IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent Application of	Date: Dec. 18, 2009
Applicants: Bednorz et al.	Docket: YO987074BZ
Serial No.: 08/479,810	Group Art Unit: 1751
Filed: June 7, 1995	Examiner: M. Kopec
Appeal No. 2009-003320	

For: NEW SUPERCONDUCTIVE COMPOUNDS HAVING HIGH TRANSITION TEMPERATURE, METHODS FOR THEIR USE AND PREPARATION

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SUPPLEMENT 2
REQUEST FOR REHEQRING
UNDER
37 C.F.R. § 41.52 (a)(1)
Of
Decision on Appeal dated 09/17/2009

ATTACHMENTS

Please charge any fee necessary to enter this paper and any previous paper to deposit account 09-0468.

Respectfully submitted,

/Daniel P Morris/
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Intellectual Property Law Dept.
P.O. Box 218
Yorktown Heights, New York 10598

ATTACHMENT BR

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O-480
(REV. 5-67)

152254 1970
Serial No. (Series of 1970)

[redacted] MAY 29 1973 PATENT NUMBER **3736048**

SERIAL NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	ASSISTANT EXAMINER
152,254	06/11/71	350	186 ~~184~~	259	Corbin

APPLICANT(S) ① GORDON HENRY COOK, DARBY, ENGLAND; ② PETER ARNOLD MERIGOLD, PRESTATYN, WALES.

~~① 48 Stoughton Rd~~
~~② 47 Maldon Rd~~

BEST COPY

TITLE OF INVENTION: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

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ASSOCIATE ATTORNEY: NONE

☐ SUBSTITUTE FOR: FILED NONE ☐

2 sh. drw transferred from SN 309,208 3/24/2

SER. NO.	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEP. CLAIMS	FILING FEE RECEIVED	ATTORNEY'S DOCKET NO.	CLAIMS ALLOWED	CLASS	SUBCLASS
152,254	780	3	27	2	$109	7955	22	350	186

CONTINUING DATA — VERIFIED. EXAMINER'S INITIALS

THIS APPLICATION IS A C-I-P OF SN 309,208, 09/16/63.

CERTIFICATE NOV 27 1973 OF CORRECTION

CLAIMS PRIORITY FOREIGN APPLICATION
MEETS CONDITIONS SPECIFIED IN 35 USC 119 YES ☑ NO ☐

Great Britain 35038 9/14/70

ASSIGNEE: The Rank Organisation Limited, London, England.

U.S. DEPT. OF COMMERCE - PATENT OFFICE

N.S.

PARTS OF APPLICATION FILED SEPARATELY

PREPARED FOR ISSUE
(Assistant Examiner) Ann M. Rehoe (Docket Clerk)

JKC EXAMINED FOR ISSUE
JOHN K. CORBIN
EXAMINER
GROUP ART UNIT 259
(Primary Examiner) Group) 259

Sheets-3 Fig-7

PRINTED PAGES: Drw'g(s) #6 | Spec(s)
ISSUE FEE DUE: $116

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NOTICE OF ALLOWANCE & ISSUE FEE DUE
Date mailed: JAN 10 1973
Date paid: 3-9-73 w.

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LICENSING & REVIEW

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6-11-71 → Reel-2746
FRAME-550-2

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350	184 186	5/72	JXC

INTERFERENCE SEARCHED

Class	Sub	Date	Ex'r
350	184–187	11/72	JXC

		5/72	11/72
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U.S. GOVERNMENT PRINTING OFFICE: 1972

SERIAL NUMBER	PATENT NUMBER
152,254	

NAME

Gordon Henry Cook

CLASS	SUBCLASS
350	186

GROUP ART UNIT	PLEASE PRINT FULL NAME
259	ASSISTANT EXAMINER
	PRIMARY EXAMINER John K. Corbin

CROSS REFERENCES (List in numerical sequence)

CLASS	SUBCLASS
350	187
350	274

INTERNATIONAL CLASSIFICATION

G02b 7/10

G02b 15/18

FORM PO-370 (REV. 3-70)

U.S. DEPARTMENT OF COMMERCE PATENT OFFICE

ISSUE CLASSIFICATION SLIP

SEARCHED

Class	Sub	Date	Exmr.
350	184 186	5/	

INTERFERENCE SEARCHED

Class	Sub	Date	Ex'r
350	184- 187	11/72	JKC

5/72 11/72

	claims	
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17	21. ✓	=
18	22. ✓	=
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20	25. ✓	=
21	26. ✓	=
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United States Patent [19]

Cook et al.

[11] 3,736,048

[45] May 29, 1973

[54] OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

[75] Inventors: **Gordon Henry Cook**, Oadby, England; **Peter Arnold Merigold**, Prestatyn, Wales

[73] Assignee: **The Rank Organization Limited**, London, England

[22] Filed: **June 11, 1971**

[21] Appl. No.: **152,254**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 309,208, Sept. 16, 1963, abandoned.

[52] **U.S. Cl.** **350/186**, 350/187, 350/214

[51] **Int. Cl.** **G02b 7/10**, G02b 15/18

[58] **Field of Search**..........................350/184, 186

[56] **References Cited**

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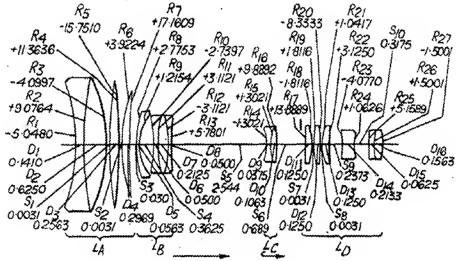
Primary Examiner—John K. Corbin
Attorney—Holcombe, Wetherill & Brisebois

[57] **ABSTRACT**

A zoom lens having an improved zooming range and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_b lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_c lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_b$ and $2.5f_b$ and the total axial movement of the third member in the range lies numerically between $0.25f_c$ and $0.5f_c$, the minimum axial separation between the second and third members occurring when the equivalent focal length of the object is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between $0.5f_c$ and $1.0f_c$.

22 Claims, 7 Drawing Figures



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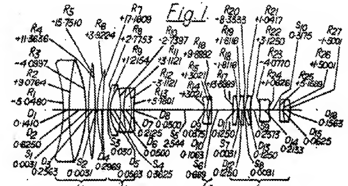


Fig. 1.

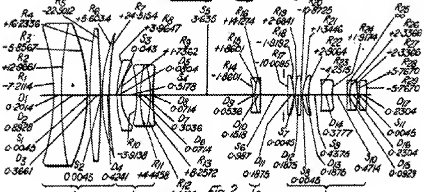


Fig. 2.

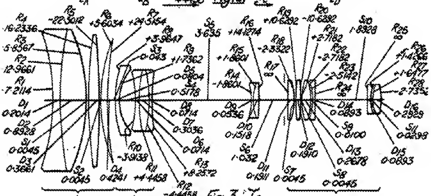


Fig. 3.

Inventor

P.A. Merigold

By G.H. Cook

Attorneys

Fig. 4.

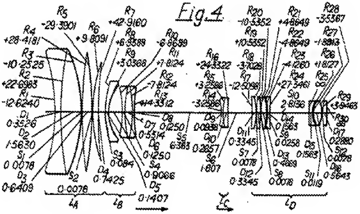


Fig. 5.

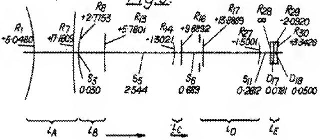
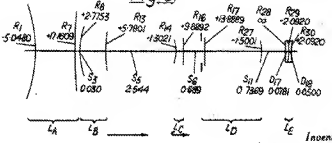
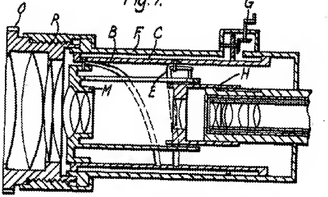


Fig. 6.



Inventor
P. A. Merigold
G. H. Cook
By [signature]
Attorneys

Fig. 7



OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

This application is a continuation-in-part of our prior application Ser. No. 309,208, filed Sept. 16, 1963, now abandoned.

This invention relates to an optical objective of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane, whereby the scale of the image can be varied, the objective being corrected for spherical and chromatic aberration, coma, astigmatism, field curvature and distortion. In this type of objective, accommodation for change of object position is usually achieved by imparting a movement, independent of the zooming relative movements, to the front member of the objective.

Many difficulties arise in the design of such objectives, and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this have usually involved the use of relatively complicated movable members in the objective in order to make it possible to stabilize the aberrations throughout the range of variation, such stabilized aberrations then being compensated in a stationary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the zoom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions or have introduced too severe optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the zooming movements for varying the equivalent focal length, so that this member is concerned only with focussing movements and is relieved of the complication of superimposing focussing movements on zooming movements. Such an arrangement is utilized in the present invention, wherein the primary object is to provide an improved arrangement of the movable zooming system of the objective, which can be employed with various different arrangements of the front member and will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

BRIEF SUMMARY OF THE INVENTION

The optical objective of the zoom type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative movements, the second and third are divergent and movable, and the fourth is convergent and stationary, the minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths f_B and f_C respectively of the movable second and third members lie numerically respectively between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective in the range of variation and between 5 and 10 times such minimum ratio, the divergent movable second member consisting of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent compound component and performing during the range of variation a total axial movement lying numerically between $1.5f_B$ and $2.5f_B$, whilst the divergent movable third member consists of a doublet component having a front surface concave to the front with radius of curvature lying numerically between $0.5f_C$ and $1.0f_C$ and performs during the range of variation a total axial movement lying numerically between $0.25f_C$ and $0.5f_C$.

Several specific examples of optical objectives as above described will be given later on in this specification, and a table will be found after the first example, together with an accompanying explanation showing the effect of varying those parameters for which ranges of variation are given in the preceding paragraph within the ranges specified in that paragraph.

It is to be understood that the terms "front" and "rear", as used herein, relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

In addition, the term "total axial movement" is used to refer to the total distance moved by a member during zooming from one end of the range to the other, independently of the direction of movement. Thus, a member may move forward and then back during the range of variation, and in this case the total axial movement is the numerical sum of the forward distance moved plus the rearward distance moved.

It should also be made clear that the term "internal contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the arithmetic mean between the radii of curvature of the individual contacting surfaces, whilst the optical power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall dimensions of the objective as small as possible and achieving the best compromise between the diameters and the relative apertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures

of the individual members, and at the same time to assist towards the desired stabilization of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

FURTHER FEATURES OF THE INVENTION

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbe V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilization of astigmatism and distortion, the radius of curvature of the front surface of the simple meniscus component of the second member preferably lies numerically between $1.5f_B$ and $3f_B$, and further assistance towards stabilization of astigmatism can be obtained by arranging for the radius of curvature of the rear surface of such component to lie numerically between $0.66f_B$ and $1.0B$. B.

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature lying numerically between $1.5f_B$ and $3f_B$, the rear surface of such component being convex to the front with radius of curvature lying numerically between $3f_B$ and $6f_B$, thus assisting towards stabilization of spherical aberration and coma.

Whilst such compound component may consist of a doublet component, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials for the various elements, facilitates correction of chromatic aberration and the desired stabilization of the other aberrations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one another by more than 0.15. The arithmetic mean between the Abbe V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5f_C$ and f_C, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25. These features contribute towards the desired stabilization of the spherical aberration and coma and also facilitate individual correction of the third member for chromatic aberration.

As in the case of the second member, it is preferable to employ materials for the elements of the third member having mean refractive indices greater than 1.65, in order to avoid excessive surface curvatures and thus

facilitate the attainment of a wide relative aperture for the member.

A movable system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially advantageous for such member to have one or more of the following characteristics:

A. The first member is preferably convergent and may comprise a front meniscus doublet component with its front and rear surfaces concave to the front followed by two simple convergent components, the front surface of the doublet component having dispersive optical power lying numerically between $0.5/f_A$ and $1.0/f_A$, where f_A is the equivalent focal length of the first member. These features permit the rear nodal point of the first member to be far to the rear and preferably behind the rear surface of the member, for cooperation with the forwardly located front nodal point of the second member.

B. The internal contact of the meniscus doublet component of the first member may be dispersive and convex to the front with radius of curvature between $1.5f_A$ and $3f_A$, the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15. These features contribute towards stabilization of spherical aberration and astigmatism over the desired focussing range to suit different object distances.

C. The two simple components of the first member may together have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4f_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than $0.75f_A$. These features assist towards stabilizing the aberrations, especially spherical aberration and astigmatism, not only throughout the range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D. The rear surface of the rear component of the first member may be convex to the front with radius of curvature between $2f_A$ and $7f_A$. This feature contributes towards stabilization of primary astigmatism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E. The axial thickness of the meniscus doublet component of the first member may be less than $0.25f_A$ and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than $0.075f_A$. These features contribute towards the desired rearward location of the rear nodal point of the first member.

F. The arithmetic mean between the Abbe V numbers of the material of the three convergent elements of the first member may exceed by at least 20 the Abbe V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G. The equivalent focal length f_A of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective. This feature as-

sists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

H. If desired, an achromatic doublet component may be provided, which can be placed at will behind the rear member of the objective to increase the value of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the objective to be stationary and to be located behind the movable third member of the objective.

DESCRIPTION OF EMBODIMENTS

Some convenient practical examples of zoom objective according to the invention are illustrated diagrammatically in the accompanying drawings, in which

FIGS. 1 – 4 respectively illustrate four examples (FIG. 4 being on half the scale of FIGS. 1 – 3),

FIGS. 5 – 6 show the example of FIG. 1 (in skeleton form) modified by the addition respectively of two alternative constructions of achromatic doublet component detachably mounted behind the rear member of the objective, and

FIG. 7 is an axial section through a lens mount having suitable zoom control element for use in carrying out the invention.

Numerical data for these six examples are given in the following tables (numbered correspondingly to the figures of the drawings), in which $R_1, R_2 \ldots$ designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, $D_1, D_2 \ldots$ designate the axial thicknesses of the individual elements of the objective, and $S_1, S_2 \ldots$ designate the axial air separations between the components of the objective. The tables also give the mean refractive indices n_d for the d-line of the spectrum and the Abbe V numbers of the materials from which the various elements of the objective are made, and in addition the clear diameters of the various surfaces of the objective.

The second section of each table gives the values of the three variable axial air separations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value F_o to its maximum value F_m are also given, together with the corresponding values of log F.

Some of the tables also have a third section giving the equation defining an axial section through an aspheric surface provided in the stationary rear member of the objective, the radius of curvature given for such surface in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms of F_o.

The insertion of equals (=) signs in the radius columns of the tables, in company with plus (+) and minus (−) signs which indicate whether the surface is convex or concave to the front, is for conformity with the usual Patent Office custom, and it is to be understood that these signs are not to be interpreted wholly in their mathematical significance. This sign convention agrees with the mathematical sign convention required for the computation of some of the aberrations including the primary aberrations, but different mathematical sign conventions are required for other purposes including computation of some of the secondary aberrations, so that a radius indicated for example as positive in the tables may have to be treated as negative for some calculations as is well understood in the art.

EXAMPLE 1

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
R_1 = −5.0480				R_1 3.4435
	D_1 = 0.1410	1.7847	26.10	
R_2 = +9.0764				R_2 3.4750
	D_2 = 0.0250	1.51007	58.35	
R_3 = −4.0997				R_3 3.4870
	S_1 = 0.0031			
R_4 = +11.2658				R_4 3.3716
	D_3 = 0.2563	1.717	47.96	
R_5 = −15.7618				R_5 3.3610
	S_2 = 0.0031			
R_6 = +8.9235				R_6 3.3035
	D_4 = 0.2063	1.717	47.96	
R_7 = +17.1800				R_7 3.0707
	S_3 = Variable			
R_8 = +2.7755				R_8 1.7000
	D_5 = 0.0563	1.60784	56.19	
R_9 = +1.2354				R_9 1.4812
	S_4 = 0.3325			
R_{10} = −2.7387				R_{10} 1.4713
	D_6 = 0.0500	1.60734	56.19	
R_{11} = +3.1121				R_{11} 1.4093
	D_7 = 0.2125	1.7847	26.10	
R_{12} = −3.3131				R_{12} 1.3947
	D_8 = 0.0500	1.69734	56.10	
R_{13} = +5.7801				R_{13} 1.3513
	S_5 = Variable			
R_{14} = −1.3081				R_{14} 0.7803
	D_9 = 0.0375	1.69734	56.13	
R_{15} = +1.3081				R_{15} 0.8205
	D_{10} = 0.1953	1.7847	26.10	
R_{16} = +9.3993				R_{16} 0.9300
	S_6 = Variable			
R_{17} = +18.0001				R_{17} 0.9055
	D_{11} = 0.1200	1.523	58.87	
R_{18} = −1.9118				R_{18} 0.9017
	S_7 = 0.0031			
R_{19} = +1.9816				R_{19} 0.9057
	D_{12} = 0.3250	1.541	58.87	
R_{20} = −8.3333				R_{20} 0.9102
	S_8 = 0.0031			
R_{21} = +1.0417				R_{21} 0.8858
	D_{13} = 0.1350	1.523	58.87	
R_{22} = +3.5280				R_{22} 0.8502
	S_9 = 0.2213 *			
R_{23} = −4.0770				R_{23} 0.7580
	D_{14} = 0.3333	1.7283	28.66	
R_{24} = +5.0626				R_{24} 0.8007
	S_{10} = 0.3155			
R_{25} = +5.1669				R_{25} 0.7107
	D_{15} = 0.0625	1.7283	28.38	
R_{26} = +1.5001				R_{26} 0.7200
	D_{16} = 0.1563	1.61459	58.23	
R_{27} = −1.5001				R_{27} 0.7225

* Aspheric.

S_3	S_5	S_6	F	log F
0.03023	2.54423	0.68858	1.00000	0.00
1.11409	1.40738	0.74157	1.77827	0.25
1.93430	0.60333	0.72521	3.16227	0.50
2.55076	0.16104	0.55123	5.62339	0.75
2.96233	0.16657	0.13414	10.00000	1.00

Equation for aspheric surface R_{23}

$$\underline{x} = -4.077 + \sqrt{16.62193 - y^2} - 0.02459203\ \underline{y}^4 + 0.08899172\ y^6 - 0.2440590\ y^8 - 0.07442450\ \underline{y}^{10}$$

The foregoing Example describes a complete thick lens design, with values calculated in many cases to the fourth decimal place, and several additional Examples of this type will be given subsequently.

It is, however, obviously impractical to provide such fully calculated thick lens designs for values broadly distributed throughout the previously specified ranges for all the significant parameters.

However, in order to show the effect of altering the principal parameters within the ranges specified for those parameters, and demonstrate the practicality of designing lenses having parameter values near the ex-

tremes of the specified ranges, an illustrative table is given below. The parameters given are all thin lens parameters (parameters of the thin lens construction on which Example I is based) and the effects of these parameter variations are shown on the dimensions of the overall objective and the relative apertures (*f*-numbers) of the first three members.

In the following table:

F_B is the focal length of the second member;
F_C is the focal length of the third member;
T_B is the total axial movement of the second member;
T_C is the total axial movement of the third member;
R is the minimum value of the ratio of the focal length of the complete objective to its *f*-number;
L is the overall length from the front of the objective to the focal plane;
D is the maximum diameter at the front of the objective;
F_{N1} is the relative aperture of the first member;
F_{N2} is the relative aperture of the second member; and
F_{N3} is the relative aperture of the third member.

The four critical thin lens parameters set forth in the fifth paragraph of this specification and in the main claim are F_B, F_C, T_B, and T_C, and their values for Example I are shown in line 1 of the table. In line 2, F_B is put equal to the lower limit (4R) of the main claim, and in line 3 equal to the upper limit (8R). In lines 4 and 5 F_C is treated similarly. T_B and T_C are dealt with in similar manner in lines 6 and 7 and lines 8 and 9. It is not possible to vary the four parameters completely independently of one another (this is referred to again later), and in fact when one parameter is set to an end limit, at least two of the others have been adjusted, in the table, so that the range of variation of focal length remains approximately unchanged.

Line 3 shows the effect of putting F_B to its upper limit. Conversely, from the changes in L, D, F_{N1}, F_{N2} and F_{N3}, it can be seen that such a modified thin lens construction would be suitable for development of a final objective of relatively simple construction constructed to cover relatively large image format dimensions (at which scale high complexity would not be permissible) at a smaller relative aperture than Example I.

Lines 4 and 5 show identical effects achievable by putting F_C at its lower and upper limits.

Line 6 shows the effect of putting the total axial movement of the second member at its upper limit. In fact, in order to do this, it is necessary to put at least either F_B or F_C at or near its end limit. This is dictated by the fundamental laws of optics, also bearing in mind the requirement to keep the focal range roughly the same. However, the effect is now not quite the same as in lines 2 to 5, because one axial movement now also lies at its end limit. Thus, the change in L and D from Example I is reduced, while the relative aperture of one member (the third member) is increased but the other two are reduced. Lines 7 to 9 show similar effects; in extent from Example I, as also are F_{N1}, F_{N2} and F_{N3}. Reverting to line 6 in particular, this modification is suited to a moderately small but not extremely small dimensional scale of final objective having a medium relative aperture, wherein the smaller relative aperture of the third member either permits its complexity to be reduced or, more usefully, its existing complexity utilized to achieve an extremely high standard of aberration correction. Corresponding but slightly different effects can be seen from the modifications of lines 7 to 9.

In general therefore, it can readily be seen from the table how the parameters of the main claim can be taken to their end limits to provide differing effects suited to differing initial requirements. The lens de-

	F_B	F_C	T_B	T_C	L	D	F_{N1}	F_{N2}	F_{N3}
Example I	−1.47	−1.82	2.93	0.66	3.62	2.91	1.59	1.0	2.29
F_B=1.0 (4R)	−1.0	−1.82	2.24	0.59	2.93	2.50	1.34	0.82	2.18
F_B=2.0 (8R)	−2.0	−1.82	3.90	0.79	4.30	3.13	1.74	1.04	2.39
F_C=1.25 (5R)	−1.47	−1.25	2.46	0.58	3.11	2.80	1.40	1.00	1.67
F_C=2.5 (10R)	−1.47	−2.50	3.38	0.77	4.07	2.94	1.74	0.98	3.07
T_B2.5 (2.5F_B)	−1.0	−3.20	2.50	0.80	3.18	2.82	1.44	0.81	2.78
T_B3.0 (1.5F_B)	−2.0	−1.22	3.05	0.69	3.86	2.67	1.84	1.05	1.76
T_C0.98 (0.39F_C)	−1.8	−2.50	2.57	0.98	3.24	2.95	1.48	0.91	2.94
T_C0.72 (0.5F_C)	−2.0	−1.44	3.23	0.72	3.92	2.00	1.63	1.05	1.67

Example I is a zoom lens intended for construction to a medium dimensional scale to cover average format dimensions.

In line 2, the effect of putting F_B to its lower limit is to reduce L and D. F_{N1}, F_{N2} and F_{N3} are also reduced, meaning that each individual member has a wider relative aperture. Because of their wider relative apertures, these members would have to be more complex (contain more usable thick lens parameters) than they are in Example I, in order to achieve the same high standard of aberration correction. However, this greater complexity would be acceptable for a zoom objective built to a small dimensional scale covering small image format dimensions. Such a small scale construction would readily be possible in view of the reductions in L and D. Therefore, a zoom lens within the scope of the main claim, with F_B at or near its lower limit, would be preferred for a lens of wider relative aperture but constructed to a smaller dimensional scale than Example I.

signer given the main claim and having a particular end requirement can work accordingly.

The table also demonstrates the sense of the end limits. For example, to take F_B below the value of 1.0(4R) in line 2 would be further to decrease L and D and further widen the relative apertures of the second, third and fourth members. Obviously a question of opinion is involved at this point, but the opinion of the inventor is that the complexity of construction for the second to fourth members, in order to achieve good aberration correction at the further widened relative aperture, would render a practical construction a non-commercial proposition. Likewise to take F_B beyond the value of 2.0(8R) in line 3 would only permit construction of a practical corrected objective to such a large dimensional scale that it would find no useful application. The same factors also arise in the modifications of lines 6 to 9, when coupled with the requirement to maintain a large range of variation of focal length, which is an essential object of the invention.

EXAMPLE II

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1=-7.2114$	$D_1=0.2014$	1.7847	28.10	R_1 4.9192
$R_2=+12.0861$	$D_2=0.8028$	1.51007	56.55	R_2 4.9542
$R_3=-5.5587$	$S_1=0.0045$			R_3 4.9814
$R_4=+16.2338$	$D_3=0.3801$	1.7170	47.90	R_4 4.8164
$R_5=-22.5012$	$S_2=0.0045$			R_5 4.8014
$R_6=+5.6934$	$D_4=0.4281$	1.7170	47.90	R_6 4.4835
$R_7=+24.5154$	$S_3=$Variable			R_7 4.3867
$R_8=+3.9947$	$D_5=0.0594$	1.69734	56.19	R_8 2.4288
$R_9=+1.7302$	$S_4=0.5175$			R_9 2.1161
$R_{10}=-2.0318$	$D_6=0.0714$	1.69734	56.10	R_{10} 2.1018
$R_{11}=+4.4458$	$D_7=0.2030$	1.7847	28.10	R_{11} 2.0132
$R_{12}=-4.4458$	$D_8=0.0714$	1.69734	56.10	R_{12} 1.9225
$R_{13}=+8.2572$	$S_5=$Variable			R_{13} 1.9161
$R_{14}=-1.8801$	$D_9=0.0588$	1.69734	56.10	R_{14} 1.1159
$R_{15}=+1.8801$	$D_{10}=0.1518$	1.7847	28.10	R_{15} 1.1721
$R_{16}=+14.1274$	$S_6=$Variable			R_{16} 1.1857
$R_{17}=-10.0095$	$D_{11}=0.1875$	1.5108	64.20	R_{17} 1.2553
$R_{18}=-1.9192$	$S_7=0.0045$			R_{18} 1.2861
$R_{19}=+2.6841$	$D_{12}=0.1875$	1.5108	64.20	R_{19} 1.3110
$R_{20}=-10.8725$	$S_8=0.0045$			R_{20} 1.3023
$R_{21}=+1.8446$	$D_{13}=0.1875$	1.5108	64.20	R_{21} 1.2872
$R_{22}=+2.8054$	$S_9=0.4875$*			R_{22} 1.2220
$R_{23}=-4.2815$	$D_{14}=0.5727$	1.7285	28.66	R_{23} 1.0608
$R_{24}=+1.9274$	$S_{10}=0.4724$			R_{24} 0.9865
$R_{25}=\infty$	$D_{15}=0.0889$	1.7285	28.66	R_{25} 1.0010
$R_{26}=+2.3856$	$D_{16}=0.2804$	1.61842	59.27	R_{26} 1.0068
$R_{27}=-2.3856$	$S_{11}=0.0045$			R_{27} 1.0156
$R_{28}=+5.7870$	$D_{17}=0.2804$	1.61842	59.27	R_{28} 1.0058
$R_{29}=-5.7870$				R_{29} 0.9776

*Aspheric.

S_3	S_5	S_6	F	log F
0.04318	3.63462	0.98730	1.00000	0.00
1.59156	2.01054	1.06300	1.77827	0.25
2.76329	0.86219	1.03962	3.16227	0.50
3.64395	0.23003	0.79109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

Equation for aspheric surface R_{23}

$$x = -4.2315 + \sqrt{17.90559 - y^2} - 0.01666805\, y^4 + 0.02010843\, y^6 - 0.00176346\, y^8 - 0.00553820\, y^{10}$$

EXAMPLE III

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1=-7.2114$	$D_1=0.2014$	1.7847	28.10	R_1 4.9192
$R_2=+12.0861$	$D_2=0.8028$	1.51007	56.55	R_2 4.9542
$R_3=-5.5587$	$S_1=0.0045$			R_3 4.9814
$R_4=+16.2338$	$D_3=0.3801$	1.7170	47.90	R_4 4.8164
$R_5=-22.5012$	$S_2=0.0045$			R_5 4.8014
$R_6=+5.6934$	$D_4=0.4281$	1.7170	47.90	R_6 4.4835
$R_7=+24.5154$	$S_3=$variable			R_7 4.3867
$R_8=+3.9947$	$D_5=0.0594$	1.69734	56.19	R_8 2.4296
$R_9=+1.7302$	$S_4=0.5175$			R_9 2.1161
$R_{10}=-2.0318$	$D_6=0.0714$	1.69734	56.10	R_{10} 2.1019
$R_{11}=+4.4458$	$D_7=0.2033$	1.7847	28.10	R_{11} 2.0132
$R_{12}=-4.4458$	$D_8=0.0714$	1.69734	56.10	R_{12} 1.9230
$R_{13}=+8.2572$	$S_5=$variable			R_{13} 1.9161
$R_{14}=-1.8503$	$D_9=0.0588$	1.69734	56.10	R_{14} 1.1159
$R_{15}=+1.8503$	$D_{10}=0.1518$	1.7847	28.10	R_{15} 1.1721
$R_{16}=+14.1274$	$S_6=$variable			R_{16} 1.1857
$R_{17}=\infty$	$D_{11}=0.1911$	1.524	58.87	R_{17} 1.2920
$R_{18}=-2.3232$	$S_7=0.0045$			R_{18} 1.3096
$R_{19}=+10.8593$	$D_{12}=0.1910$	1.524	58.87	R_{19} 1.3286
$R_{20}=-10.0262$	$S_8=0.0045$			R_{20} 1.3086
$R_{21}=+2.7913$	$D_{13}=0.3078$	1.61842	50.27	R_{21} 1.3273
$R_{22}=-2.7913$	$S_9=0.0100$			R_{22} 1.3060
$R_{23}=-2.5142$	$D_{14}=0.0883$	1.72830	28.38	R_{23} 1.3040
$R_{24}=\infty$	$S_{10}=1.8328$			R_{24} 1.2883
$R_{25}=\infty$	$D_{15}=0.0823$	1.72830	28.38	R_{25} 0.9600
$R_{26}=+1.4266$	$S_{11}=0.0293$			R_{26} 0.9800
$R_{27}=+1.6477$	$D_{16}=0.2629$	1.69784	56.10	R_{27} 0.9800
$R_{28}=-2.7352$				R_{28} 0.9300

S_3	S_5	S_6	F	log F
0.04318	3.63462	1.0319	1.00000	0.00
1.59156	2.01054	1.1076	1.77827	0.25
2.76329	0.86219	1.08422	3.16227	0.50
3.64395	0.23003	0.83569	5.62339	0.75
4.23190	0.23796	0.23984	10.00000	1.00

EXAMPLE IV

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
$R_1=-12.8240$	$D_1=0.3528$	1.7847	28.10	R_1 8.6159
$R_2=+22.6583$	$D_2=1.2830$	1.51007	56.55	R_2 8.5960
$R_3=-10.2525$	$S_1=0.0078$			R_3 8.7208
$R_4=+25.4181$	$D_3=0.5409$	1.7170	47.90	R_4 8.4314
$R_5=-30.3301$	$S_2=0.0078$			R_5 8.4692
$R_6=+6.8091$	$D_4=0.7425$	1.7170	47.90	R_6 7.7612
$R_7=+42.0160$	$S_3=$Variable			R_7 7.6732
$R_8=+6.9388$	$D_5=0.1407$	1.65831	56.83	R_8 4.2510
$R_9=+3.0358$	$S_4=0.9068$			R_9 3.7045
$R_{10}=-6.3800$	$D_6=0.1250$	1.65831	56.83	R_{10} 3.6795
$R_{11}=+7.8124$	$D_7=0.5314$	1.75503	28.00	R_{11} 3.5240
$R_{12}=-7.8124$	$D_8=0.1250$	1.65831	56.83	R_{12} 3.4670
$R_{13}=+34.3312$	$S_5=$Variable			R_{13} 3.3528
$R_{14}=-3.2588$	$D_9=0.0938$	1.65831	56.83	R_{14} 1.9320
$R_{15}=+8.2588$	$D_{10}=0.2657$	1.75503	28.00	R_{15} 2.0326
$R_{16}=+24.3923$	$S_6=$Variable			R_{16} 2.0774
$R_{17}=-12.5095$	$D_{11}=0.3343$	1.65031	58.60	R_{17} 2.2574
$R_{18}=-3.7028$	$S_7=0.0078$			R_{18} 2.3289
$R_{19}=+10.5852$	$D_{12}=0.3343$	1.65031	58.60	R_{19} 2.3311
$R_{20}=-10.5852$	$S_8=0.0078$			R_{20} 2.3181
$R_{21}=+1.8640$	$D_{13}=0.4689$	1.61817	50.27	R_{21} 2.2557
$R_{22}=-4.8640$	$S_9=0.0286$			R_{22} 2.2250
$R_{23}=-4.1200$	$D_{14}=0.1563$	1.7282	28.08	R_{23} 2.2243
$R_{24}=+27.3461$	$S_{10}=2.8125$			R_{24} 2.1501
$R_{25}=\infty$	$D_{15}=0.1563$	1.76128	25.98	R_{25} 1.7374
$R_{26}=+1.8127$	$S_{11}=0.0130$			R_{26} 1.7350
$R_{27}=+1.8013$	$D_{16}=0.5849$	1.65031	58.60	R_{27} 1.7382
$R_{28}=-5.5387$	$S_{12}=0.0078$*			R_{28} 1.7741
$R_{29}=+5.0480$	$D_{17}=0.3890$	1.65031	58.60	R_{29} 1.7554
$R_{30}=\infty$				R_{30} 1.7100

* Aspheric.

S_2	S_3	S_4	F	log F
0.08428	6.36327	1.80704	1.00000	0.0
2.79513	3.51989	1.93956	1.77827	0.25
4.84654	1.50941	1.89864	3.16227	0.5
6.38837	0.40269	1.46152	5.62339	0.75
7.41774	0.41652	0.42033	10.00000;	1.0

Equation for aspheric surface R_{19}

$$\underline{x} = +3.9463 - \sqrt{15.37328 - \underline{y}^2} + 0.00427020\, \underline{y}^4 - 0.00777096\, \underline{y}^6 + 0.00721693\, \underline{y}^{10}$$

In all these examples, the maximum value F_∞ of the equivalent focal length F of the objective is ten times the minimum value F_o thereof. Example I is corrected for a relative aperture $f/4.0$, whilst Examples II and III are each corrected for a relative aperture $f/2.8$, and Example IV is corrected for a relative aperture of $f/1.6$. Examples II and III differ from one another solely in the stationary rear member L_D, the front three members L_A, L_B and L_C being identical in the two examples. Such members L_A, L_B and L_C are in fact similar to the front three members L_A, L_B and L_C of Example I, the dimensions being scaled up from those of Example I in the ratio of the f-numbers, that is in the ratio of 4.0/2.8. The rear members L_D in Examples II and III are, however, not scaled-up versions of the rear member L_D of Example I. The front three members L_A, L_B, L_C of Example IV, which includes yet another alternative construction of rear member L_D, are of the same general type as those of Examples I–III, but their numerical dimensions differ somewhat from a version of those of Example I scaled up in the ratio 4.0/1.6.

All these examples cover a semi-angular field of view varying from 27 degrees at F_o to 2.7 degrees at F_∞.

The iris diaphragm in all four examples is stationary and is located between the movable third member L_C and the stationary rear member L_D. In Example I the diaphragm is 0.0625 F_o in front of the surface R_{12} and has diameter 0.8568 F_o; in Example II the diaphragm is 0.0929 F_o in front of the surface R_{13} and has diameter 1.2240 F_o; in Example III the diaphragm is 0.1375 F_o in front of the surface R_{13} and has diameter 1.2240 F_o; and in Example IV the diaphragm is 0.2407 F_o in front of the surface R_{13} and has diameter 2.1446 F_o.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F_o in Example I, 2.6761 F_o in Example II, 2.3027 F_o in Example III and 1.7878 F_o in Example IV.

The equivalent focal length f_A of the stationary first member L_A is + 4.4551 F_o in Example I, + 6.3644 F_o in Examples II and III and + 11.1415 F_o in Example IV; the equivalent focal length f_B of the movable second member L_B is − 1.4703 F_o in Example I, − 2.1004 F_o in Examples II and III and − 3.6770 F_o in Example IV; the equivalent focal length f_C of the movable third member L_C is − 1.8176 F_o in Example I, − 2.5966 F_o in Examples II and III and − 4.5458 F_o in Example IV; and the equivalent focal length f_D of the stationary fourth member L_D is + 1.4753 F_o in Example I, + 2.1286 F_o in Example II, + 2.3232 F_o in Example III and + 4.0419 F_o in Example IV; the positive and negative signs respectively indicating convergence and divergence.

In all four examples, the convergent stationary front member L_A consists of a meniscus doublet component followed by two convergent simple components. The front surface R_1 of the doublet component is concave to the front and has dispersive optical power numerically equal to 0.155/F_o or 0.692/f_A in Example I, to 0.109/F_o or 0.692/f_A in Examples II and III, and to 0.062/F_o or 0.692/f_A in Example IV. The internal contact R_2 of the doublet component is dispersive and convex to the front and has radius of curvature equal to 2.037 f_A in all four examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is 0.27 in all four examples.

The combined equivalent focal length of the two simple components of the first member L_A is 4.0013 F_o in Example I, 5.7162 F_o in Examples II and III, and 10.0064 F_o in Example IV or 0.8981 f_A in all four examples. The radius of curvature R_4 of the front surface of the first of such simple components is 2.551 f_A in all four examples, and the radius of curvature R_6 of the front surface of the second of such simple components is 0.880 f_A in all four examples. The rear surface R_7 of such second simple component is convex to the front with radius of curvature 3.852 f_A in all four examples.

The axial thickness (D_1 + D_2) of the meniscus doublet component of the first member L_A is 0.766 F_o in Example I, 1.094 F_o in Examples II and III, and 1.916 F_o in Example IV, or 0.172 f_A in all four examples. The sum of the axial thicknesses of the two simple components (D_3 + D_4) of the first member is 0.553 F_o in Example I, 0.790 F_o in Examples II and III, and 1.383 F_o in Example IV, or 0.124 f_A in all four examples.

The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member L_A in all four examples is 50.72 and thus exceeds the Abbe V number of the material of the divergent front element by 24.62.

The maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective is 2.5 F_o in Example I, 3.57 F_o in Examples II and III, and 6.25 F_o in Example IV, so that in all four examples f_A is 1.782 times such maximum value.

In all four examples, the minimum separation between the movable second and third members L_B and L_C occurs when the equivalent focal length of the objective is 7.45 F_o, and the numerical values of the equivalent focal lengths f_B and f_C of such members are respectively 5.88 and 7.27 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective.

The movable second member L_B in all four examples consists of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent element between two divergent elements, and its total axial movement (a unidirectional rearward movement) in the range of variation is numerically equal to 1.994 f_B. The front and rear surfaces R_8 and R_9 of the simple meniscus component of such member respectively have radii of curvature numerically equal to 1.89 f_B and 0.83 f_B in all four examples, whilst the front and rear surfaces R_{10} and R_{13} of the triplet component respectively have radii of curvature numerically equal to 1.86 f_B in Examples I – III and 1.87 f_B in Example IV and to 3.93 f_B in Examples I–III and 3.99 f_B in Example IV.

The movable third member L_C in all four examples consists of a doublet component, whose front surface R_{14} is concave to the front with radius of curvature numerically equal to 0.72 f_C, and the total axial movement (the numerical sum of an initial forward movement

plus a subsequent rearward movement) of such member is numerically equal to 0.363 f_C. The internal contact R_{15} of such doublet component is collective and convex to the front, with radius of curvature numerically equal to 0.72 f_C. The difference between the mean refractive indices of the materials of such doublet component is 0.087 in Examples I – III and 0.088 in Example IV, the difference between their Abbe V numbers being 30.09 in Examples I – III and 30.24 in Example IV.

In all four examples, the various aberrations are well stabilized in the front three members L_A, L_B, L_C throughout the range of variation of equivalent focal length of the objective and also throughout the focussing range, and the stationary rear member L_D serves to balance out such residual stabilized aberrations, and also to locate the resultant image plane in a convenient position. The construction of such rear member may thus vary widely.

In Examples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilized aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R_{25} of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and coma with minimum effect on oblique aberrations.

In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no aspheric surface is used in the actual example given, some further improvement in aberration correction could be achieved by incorporating such a surface.

Yet another alternative construction for the stationary rear member L_D is employed in Example IV, consisting of seven simple components, the first three and the last two being convergent, and the fourth and fifth divergent. An aspheric surface is again used, in this case the front surface R_{29} of the rearmost component.

It is often desired in practice to provide two different ranges of variation of the equivalent focal length of the objective, and with the objective according to the present invention this can be carried out in a simple way by the provision of an achromatic doublet component, which can be placed at will behind the stationary rear member L_D of the objective, such doublet component, when in position, acting to move the resultant image plane further from the rear surface of the member L_D and to increase the values of the equivalent focal length of the objective in the same proportion throughout the range. Another effect of the addition of this doublet component is to reduce the relative aperture of the objective and the angular field covered. Numerical data are given below of two alternative examples of achromatic doublet component suited to follow the rear member L_D of Example I above. FIGS. 5 and 6 respectively show these two examples of doublet component L_E in position behind the main objective, which for simplicity is shown only in skeleton form, the front and rear surfaces only being shown for each of the four members L_A, L_B, L_C and L_D of the objective.

EXAMPLE V

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
	S_{11}=0.2813			
R_{28}=∞				R_{28} 0.7312
	D_{12}=0.0781	1.70085	33.28	
R_{29}=−2.0926				R_{29} 0.7315
	D_{13}=0.0500	1.60483	43.83	
R_{30}=+8.8426				R_{30} 0.7352

EXAMPLE VI

Radius	Thickness or air separation	Refractive index n_d	Abbe V number	Clear diameter
	S_{11}=0.7580			
R_{28}=∞				R_{28} 0.6740
	D_{12}=0.0781	1.70085	30.28	
R_{29}=−2.0620				R_{29} 0.6740
	D_{13}=0.0500	1.60562	52.31	
R_{30}=+2.0620				R_{30} 0.6740

The dimensions in these two examples of achromatic doublet component are given in terms of the minimum value F_a of the equivalent focal length for the objective of Example I. In each table S_{11} represents the air separation between the rear surface R_{27} of the stationary rear member L_D of Example I and the front surface R_{28} of the added doublet component. The doublet component in each case consists of a convergent element in front of a divergent element.

The added doublet component L_E of Example V increases the values of the equivalent focal length in the ratio 3:2, so that the normal range from F_a to 10 F_a is altered by the doublet component into a range from 1.5 F_a to 15 F_a. The doublet component of Example VI acts to double the values of the equivalent focal length of Example I, thus giving a range from 2 F_a to 20 F_a when the doublet component is in position.

The back focal distance from the rear surface R_{30} of the added doublet component L_E to the new position of the resultant image plane is 3.704 F_a in Example V and 4.028 F_a in Example VI. The relative aperture of the objective is changed from $f/4.0$ by the addition of the doublet component to $f/6.0$ in Example V and $f/8.0$ in Example VI. The semi-angular field, which for Example I alone varies from 27 degrees at F_a to 2.7 degrees at F_m, varies (when the doublet component of Example V is added) from 18 degrees at 1.5 F_a to 1.8 degrees at 15 F_a, and (when the doublet component of Example VI is added) from 13.5 degrees at 2 F_a to 1.35 degrees at 20 F_a.

It will be realized that the addition of only an achromatic doublet component to an already well-corrected objective must necessarily result in a lower standard of aberration correction when the doublet component is in place. But the increased equivalent focal length and reduced relative aperture and angular field do not call for so high a standard of correction as is needed when the objective is used alone, and for many practical purposes the standard of correction obtained with the dou-

blet component added is adequate.

The necessary axial movement of the second and third members may be brought about in various ways, for example by means of two appropriately shaped cams, which may be in the form of cam grooves B and E on the inner surface of a tubular member C rotated by the zoom control element G and surrounding the second and third members M and H, which are held against rotation relatively to the fixed casing F of the objective. The focussing movement of the front member P may be effected under the control of a focussing control element O by mounting the front member in screw threaded engagement with the fixed casing F of the objective.

It will be appreciated that the foregoing examples have been given by way of example only and that the invention can be carried into practice in other ways.

We claim

1. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane), corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, said objective having a maximum equivalent focal length at least 6 times its minimum focal length, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_B lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_C lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_B$ and $2.5f_B$ and the total axial movement of the third member in the range lies numerically between $0.25f_C$ and $0.5f_C$, the minimum axial separation between the second and third member occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front.

2. An optical objective as claimed in claim 1, in which the compound component in the divergent movable second member includes at least one convergent element and at least one divergent element made of materials of differing Abbe V numbers.

3. An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front.

4. An optical objective as claimed in claim 3, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

5. An optical objective as claimed in claim 4, in which the doublet component constituting the third member has a collective internal contact convex to the front.

6. An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front.

7. An optical objective as claimed in claim 2, in which the doublet component constituting the third member has a collective internal contact convex to the front, and the materials of the two elements of such component having differing Abbe V numbers and differing mean refractive indices.

8. An optical objective as claimed in claim 1, in which the front surface of the compound component of the second member is concave to the front and the rear surface of such component is convex to the front.

9. An optical objective as claimed in claim 8, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements, the materials of all the elements of the second member having mean refractive indices greater than 1.69 and being such that the arithmetic mean between the Abbe V numbers of the materials of the divergent elements exceeds that of the convergent element.

10. An optical objective as claimed in claim 9, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

11. An optical objective as claimed in claim 1, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

12. An optical objective as claimed in claim 11, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature substantially equal to $0.72f_C$, the materials of the two elements of such component having Abbe V numbers which differ by about 30 and mean refractive indices which are each greater than 1.69 and differ by about 0.09.

13. An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature substantially equal to $0.72f_C$, the difference between the mean refractive indices of the materials of the two elements of such component being about 0.09, while the difference between the Abbe V numbers of such materials is about 30.

14. An optical objective as claimed in claim 13, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

15. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining

constant position of the image plane), corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_b lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the *f*-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_C lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_B$ and $2.5f_B$ and the total axial movement of the third member in the range lies numerically between $0.25f_C$ and $0.5f_C$, the minimum axial separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, the movable divergent third member consisting of a doublet component having its front surface concave to the front, and the first member of the objective comprises a meniscus doublet component having a front surface which is concave to the front and two simple convergent components behind such meniscus doublet component.

16. An optical objective as claimed in claim **15**, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front.

17. An optical objective as claimed in claim **16**, in which the compound component in the divergent movable second member includes at least one convergent element and at least one divergent element, and the doublet component constituting the third member has a collective internal contact convex to the front.

18. An optical objective as claimed in claim **15**, in which the two simple components of the first member together have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being greater than twice the radius of curvature of the front surface of the second of such simple components, the rear surface of the second of the two simple components being convex to the front.

19. An optical objective as claimed in claim **15**, in which the axial thickness of the meniscus doublet component of the first member is is greater than the sum of the axial thicknesses of the two simple components of the first member.

20. An optical objective as claimed in claim **19**, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

21. An optical objective as claimed in claim **15**, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

22. An optical objective as claimed in claim **21**, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front with radius of curvature substantially equal to $2.04f_A$, the difference between the mean refractive indices of the materials of the two elements of the doublet being substantially 0.27.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,736,048 Dated May 29, 1973

Inventor(s) GORDON HENRY COOK and PETER ARNOLD MERIGOLD

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

[73] Assignee: The Rank Organisation Limited
London, England

[30] Foreign Application Priority Data
Sept. 14, 1962 Great Britain..........35088

Signed and sealed this 27th day of November 1973.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

6500-101-A
5,500-102

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R. Bilenj 11/24/71

TO ALL WHOM IT MAY CONCERN:

Be it known that we, Gordon Henry Cook and Peter Arnold Merigold, Subjects of the Queen of England, and residents of Cadby, County of Leicester, England, and Prestatyn, County of Flintshire, Wales, United Kingdom respectively, have invented certain new and useful improvements in Optical Objectives of Variable Equivalent Focal Length, of which the following is a specification:-

TITLE OF THE INVENTION

OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

ABSTRACT OF THE DISCLOSURE

A zoom lens having an improved zooming range and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_B lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_C lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_B$ and $2.5f_B$ and the total axial movement of the third member in the range lies numerically between $0.25f_C$ and $0.5f_C$, the minimum axial separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component,

and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between $0.5f_0$ and $1.0f_0$.

BACKGROUND TO THE INVENTION

This application is a continuation-in-part of our prior application Serial No. 309,208, filed September 16, 1963, now abandoned.

This invention relates to an optical objective of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane, whereby the scale of the image can be varied, the objective being corrected for spherical and chromatic aberration, coma, astigmatism, field curvature and distortion. In this type of objective, accommodation for change of object position is usually achieved by imparting a movement, independent of the zooming relative movements, to the front member of the objective.

Many difficulties arise in the design of such objectives, and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this have usually involved the use of relatively complicated movable members in the objective in order to make it possible to stabilise the aberrations throughout the range of variation, such stabilized

aberrations then being compensated in a stationary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the zoom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions or have introduced too severe optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the zooming movements for varying the equivalent focal length, so that this member is concerned only with focussing movements and is relieved of the complication of superimposing focussing movements on zooming movements. Such an arrangement is utilised in the present invention, wherein the primary object is to provide an improved arrangement of the movable zooming system of the objective, which can be employed with various different arrangements of the front member and

will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

BRIEF SUMMARY OF THE INVENTION

The optical objective of the zoom type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative movements, the second and third are divergent and movable, and the fourth is convergent and stationary, the minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths f_B and f_C respectively of the movable second and third members lie numerically respectively between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective in the range of variation and between 5 and 10 times such minimum ratio, the divergent movable second member consisting of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent compound component and performing during the range of variation a total axial movement lying numerically between $1.5f_B$ and $2.5f_B$, whilst the divergent movable third member consists of a doublet component having a front surface concave to the front with radius of curvature lying numerically between $0.5f_C$ and $1.0f_C$ and performs during the range of variation a total axial movement lying numerically between $0.25f_C$

and $0.5f_o$.

Several specific examples of optical objectives as above described will be given later on in this specification, and a table will be found after the first example, together with an accompanying explanation showing the effect of varying those parameters for which ranges of variation are given in the preceding paragraph within the ranges specified in that paragraph.

It is to be understood that the terms "front" and "rear", as used herein, relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

In addition, the term "total axial movement" is used to refer to the total distance moved by a member during zooming from one end of the range to the other, independently of the direction of movement. Thus, a member may move forward and then back during the range of variation, and in this case the total axial movement is the numerical sum of the forward distance moved plus the rearward distance moved.

It should also be made clear that the term "internal contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the arithmetic mean between the radii of curvature of the individual contacting surfaces, whilst the optical

power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall dimensions of the objective as small as possible and achieving the best compromise between the diameters and the relative apertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures of the individual members, and at the same time to assist towards the desired stabilization of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

FURTHER FEATURES OF THE INVENTION

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbe V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilisation of astigmatism and distortion, the radius of curvature of

the front surface of the simple meniscus component of the second member preferably lies numerically between $1.5f_B$ and $3f_B$, and further assistance towards stabilization of astigmatism can be obtained by arranging for the radius of curvature of the rear surface of such component to lie numerically between $0.66f_B$ and $1.0f_B$.

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature lying numerically between $1.5f_B$ and $3f_B$, the rear surface of such component being convex to the front with radius of curvature lying numerically between $3f_B$ and $6f_B$, thus assisting towards stabilization of spherical aberration and coma.

Whilst such compound component may consist of a doublet component, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials for the various elements, facilitates correction of chromatic aberration and the desired stabilization of the other aberrations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one another by more than 0.15. The arithmetic mean between the

Abbe V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5f_C$ and f_C, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25. These features contribute towards the desired stabilization of spherical aberration and coma and also facilitate individual correction of the third member for chromatic aberration.

As in the case of the second member, it is preferable to employ materials for the elements of the third member having mean refractive indices greater than 1.65, in order to avoid excessive surface curvatures and thus facilitate the attainment of a wide relative aperture for the member.

A movable system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially advantageous for such member to have one or more of the following characteristics:-

A) The first member is preferably convergent and

may comprise a front meniscus doublet component with its front and rear surfaces concave to the front followed by two simple convergent components, the front surface of the doublet component having dispersive optical power lying numerically between $0.5/f_A$ and $1.0/f_A$, where f_A is the equivalent focal length of the first member. These features permit the rear nodal point of the first member to be far to the rear and preferably behind the rear surface of the member, for cooperation with the forwardly located front nodal point of the second member.

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B) The internal contact of the meniscus doublet component of the first member may be dispersive and convex to the front with radius of curvature between $1.5f_A$ and $3f_A$, the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15. These features contribute towards stabilization of spherical aberration and astigmatism over the desired focussing range to suit different object distances.

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C) The two simple components of the first member may together have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4f_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than $0.75f_A$. These features assist towards stabilizing the aberrations, especially spherical aberration and astigmatism, not only throughout the

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range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D) The rear surface of the rear component of the first member may be convex to the front with radius of curvature between $2f_A$ and $7f_A$. This feature contributes towards stabilization of primary astigmatism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E) The axial thickness of the meniscus doublet component of the first member may be less than $0.25f_A$ and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than $0.075f_A$. These features contribute towards the desired rearward location of the rear nodal point of the first member.

F) The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member may exceed by at least 20 the Abbe V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G) The equivalent focal length f_A of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective. This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

H) If desired, an achromatic doublet component may be provided, which can be placed at will behind the rear member of the objective to increase the value of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the objective to be stationary and to be located behind the movable third member of the objective.

DESCRIPTION OF EMBODIMENTS

Some convenient practical examples of zoom objective according to the invention are illustrated diagrammatically in the accompanying drawings, in which

Figures 1 to 4 respectively illustrate four examples (Figure 4 being on half the scale of Figures 1 to 3),

Figures 5 and 6 show the example of Figure 1 (in skeleton form) modified by the addition respectively of two alternative constructions of achromatic doublet component detachably mounted behind the rear member of the objective, and

Figure 7 is an axial section through a lens mount having suitable zoom control element for use in carrying out the invention.

Numerical data for these six examples are given in the following tables (numbered correspondingly to the figures of the drawings), in which R_1, R_2 .... designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and

the negative sign that it is concave thereto, D_1, D_2 .... designate the axial thicknesses of the individual elements of the objective, and S_1, S_2 .... designate the axial air separations between the components of the objective. The tables also give the mean refractive indices n_d for the d-line of the spectrum and the Abbe V numbers of the materials from which the various elements of the objective are made, and in addition the clear diameters of the various surfaces of the objective.

The second section of each table gives the values of the three variable axial air separations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value F_o to its maximum value F_m are also given, together with the corresponding values of log F.

Some of the tables also have a third section giving the equation defining an axial section through an aspheric surface provided in the stationary rear member of the objective, the radius of curvature given for such surface in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms of F_o.

The insertion of equals (=) signs in the radius columns of the tables, in company with plus (+) and minus (-) signs which indicate whether the surface is convex or concave to the front, is for conformity with the usual Patent Office custom, and it is to be understood

that these signs are not to be interpreted wholly in their mathematical significance. This sign convention agrees with the mathematical sign convention required for the computation of some of the aberrations including the primary aberrations, but different mathematical sign conventions are required for other purposes including computation of some of the secondary aberrations, so that a radius indicated for example as positive in the tables may have to be treated as negative for some calculations as is well understood in the art.

Example I

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter
R_1 = − 5.0480				R_1 3.4435
	D_1 = 0.1410	1.7847	26.10	
R_2 = + 9.0764				R_2 3.4750
	D_2 = 0.6250	1.51507	56.35	
R_3 = − 4.0997				R_3 3.4870
	S_1 = 0.0031			
R_4 = + 11.3636				R_4 3.3715
	D_3 = 0.2563	1.717	47.90	
R_5 = − 15.7510				R_5 3.3610
	S_2 = 0.0031			
R_6 = + 3.9224				R_6 3.1035
	D_4 = 0.2969	1.717	47.90	
R_7 = + 17.1609				R_7 3.0707
	S_3 = variable			
R_8 = + 2.7753				R_8 1.7000
	D_5 = 0.0563	1.69734	56.19	
R_9 = + 1.2154				R_9 1.4812
	S_4 = 0.3625			
R_{10} = − 2.7397				R_{10} 1.4712
	D_6 = 0.0500	1.69734	56.19	
R_{11} = + 3.1121				R_{11} 1.4092
	D_7 = 0.2125	1.7847	26.10	
R_{12} = − 3.1121				R_{12} 1.3947
	D_8 = 0.0500	1.69734	56.19	
R_{13} = + 5.7801				R_{13} 1.3412
	S_5 = variable			
R_{14} = − 1.3021				R_{14} 0.7807
	D_9 = 0.0375	1.69734	56.19	
R_{15} = + 1.3021				R_{15} 0.8205
	D_{10} = 0.1063	1.7847	26.10	
R_{16} = + 9.8892				R_{16} 0.8300
	S_6 = variable			
R_{17} = + 13.8889				R_{17} 0.8865
	D_{11} = 0.1250	1.524	58.87	
R_{18} = − 1.8116				R_{18} 0.9017
	S_7 = 0.0031			
R_{19} = + 1.8116				R_{19} 0.9157
	D_{12} = 0.1250	1.524	58.87	
R_{20} = − 8.3333				R_{20} 0.9102
	S_8 = 0.0031			
R_{21} = + 1.0417				R_{21} 0.8858
	D_{13} = 0.1250	1.524	58.87	
R_{22} = + 3.1250				R_{22} 0.8602
	S_9 = 0.2373 (aspheric)			
R_{23} = − 4.0770				R_{23} 0.7560
	D_{14} = 0.2133	1.7283	28.66	
R_{24} = + 1.0626				R_{24} 0.6907
	S_{10} = 0.3175			
R_{25} = + 5.1589				R_{25} 0.7197
	D_{15} = 0.0625	1.7283	28.66	
R_{26} = + 1.5001				R_{26} 0.7200
	D_{16} = 0.1563	1.61452	56.22	
R_{27} = − 1.5001				R_{27} 0.7225

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TA s_3	TD s_5	TE s_6	TF F	TG log F
0.03023	2.54423	0.68858	1.00000	0.00
1.11409	1.40738	0.74157	1.77827	0.25
1.93430	0.60333	0.72521	3.16227	0.50
2.55076	0.16104	0.55123	5.62339	0.75
2.96233	0.16657	0.13414	10.00000	1.00

PS

Equation for aspheric surface R_{23}

$$x = -4.077 + \sqrt{16.62193 - y^2} - 0.02459203\, y^4 + 0.08899172\, y^6$$
$$- 0.2440590\, y^8 - 0.07442450\, y^{10}$$

The foregoing Example describes a complete thick lens design, with values calculated in many cases to the fourth decimal place, and several additional Examples of this type will be given subsequently.

It is, however, obviously impractical to provide such fully calculated thick lens designs for values broadly distributed throughout the previously specified ranges for all the significant parameters.

However, in order to show the effect of altering the principal parameters within the ranges specified for those parameters, and demonstrate the practicality of designing lenses having parameter values near the extremes of the specified ranges, an illustrative table is given below. The parameters given are all thin lens parameters (parameters of the thin lens construction on which Example I is based) and the effects of these parameter variations

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are shown on the dimensions of the overall objective and the relative apertures (f-numbers) of the first three members.

In the following table:

F_B is the focal length of the second member;

F_C is the focal length of the third member;

T_B is the total axial movement of the second member;

T_C is the total axial movement of the third member;

R is the minimum value of the ratio of the focal length of the complete objective to its f-number;

L is the overall length from the front of the objective to the focal plane;

D is the maximum diameter at the front of the objective;

F_{N1} is the relative aperture of the first member;

F_{N2} is the relative aperture of the second member; and

F_{N3} is the relative aperture of the third member.

The four critical thin lens parameters set forth in the fifth paragraph of this specification and in the main claim are F_B, F_C, T_B, and T_C, and their values for Example I are shown in line 1 of the table. In line 2, F_B is put equal to the lower limit (4R) of the main claim, and in line 3 equal to the upper limit (8R). In lines 4 and 5 F_C is treated similarly. T_B and T_C are dealt with in similar manner in lines 6 and 7 and lines 8 and 9. It is not possible to vary the four parameters completely independently of one another (this is referred to again later), and in fact when one parameter is set to an end limit, at least two of the others have been adjusted, in the table, so that the range of variation of

focal length remains approximately unchanged.

		F_B	F_C	T_B	T_C	L	D	F_{N1}	F_{N2}	F_{N3}
1	Example I	-1.47	-1.82	2.93	0.66	3.62	2.81	1.59	1.0	2.29
2	F_B-1.0 (4R)	-1.0	-1.82	2.24	0.56	2.90	2.56	1.34	0.92	2.19
3	F_B-2.0 (8R)	-2.0	-1.82	3.60	0.79	4.30	3.12	1.74	1.04	2.39
4	F_C-1.25 (5R)	-1.47	-1.25	2.44	0.58	3.11	2.69	1.40	1.00	1.67
5	F_C-2.5 (10R)	-1.47	-2.50	3.38	0.77	4.07	2.94	1.74	0.98	3.07
6	T_B2.5 (2.5F_B)	-1.0	-2.36	2.50	0.66	3.18	2.62	1.44	0.91	2.78
7	T_B3.0 (1.5F_B)	-2.0	-1.26	3.00	0.69	3.68	2.87	1.54	1.06	1.76
8	T_C0.68 (0.27F_C)	-1.0	-2.50	2.57	0.68	3.24	2.69	1.46	0.91	2.94
9	T_C0.72 (0.5F_C)	-2.0	-1.44	3.22	0.72	3.91	3.00	1.63	1.05	1.97

Example I is a zoom lens intended for construction to a medium dimensional scale to cover average format dimensions.

In line 2, the effect of putting F_B to its lower limit is to reduce L and D. F_{N1}, F_{N2} and F_{N3} are also reduced, meaning that each individual member has a wider relative aperture. Because of their wider relative apertures, these members would have to be more complex (contain more usable thick lens parameters) than they are in Example I, in order to achieve the same high standard of aberration correction. However, this greater complexity would be acceptable for a zoom objective built to a small dimensional scale covering small image format dimensions. Such a small scale construction would readily be possible in view of the reductions in L and D. Therefore, a zoom lens within the scope of the main claim, with F_B at or near its lower limit, would be preferred for a lens of wider relative aperture

but constructed to a smaller dimensional scale than Example I.

Line 3 shows the effect of putting F_B to its upper limit. Conversely, from the changes in L, D, F_{N1}, F_{N2} and F_{N3}, it can be seen that such a modified thin lens construction would be suitable for development of a final objective of relatively simple construction constructed to cover relatively large image format dimensions (at which scale high complexity would not be permissible) at a smaller relative aperture than Example I.

Lines 4 and 5 show identical effects achievable by putting F_C at its lower and upper limits.

Line 6 shows the effect of putting the total axial movement of the second member at its upper limit. In fact, in order to do this, it is necessary to put at least either F_B or F_C at or near its end limit. This is dictated by the fundamental laws of optics, also bearing in mind the requirement to keep the focal range roughly the same. However, the effect is now not quite the same as in lines 2 to 5, because one axial movement now also lies at its end limit. Thus, the change in L and D from Example I is reduced, while the relative aperture of one member (the third member) is increased but the other two are reduced. Lines 7 to 9 show similar effects; in extent from Example I, as also are F_{N1}, F_{N2} and F_{N3}. Reverting to line 6 in particular, this modification is suited to a moderately small but not extremely small dimensional scale of final objective having a medium relative aperture, wherein the smaller

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relative aperture of the third member either permits its complexity to be reduced or, more usefully, its existing complexity utilised to achieve an extremely high standard of aberration correction. Corresponding but slightly different effects can be seen from the modifications of lines 7 to 9.

In general therefore, it can readily be seen from the table how the parameters of the main claim can be taken to their end limits to provide differing effects suited to differing initial requirements. The lens designer given the main claim and having a particular end requirement can work accordingly.

The table also demonstrates the sense of the end limits. For example, to take F_B below the value of 1.0(4R) in line 2 would be further to decrease L and D and further widen the relative apertures of the second, third and fourth members. Obviously a question of opinion is involved at this point, but the opinion of the inventor is that the complexity of construction for the second to fourth members, in order to achieve good aberration correction at the further widened relative aperture, would render a practical construction a non-commercial proposition. Likewise to take F_B beyond the value of 2.0(8R) in line 3 would only permit construction of a practical corrected objective to such a large dimensional scale that it would find no useful application. The same factors also arise in the modifications of lines 6 to 9, when coupled with the requirement to maintain a large range of variation of focal length, which is an essential object of the invention.

Example II

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter
R_1 = − 7.2114				R_1 4.9192
	D_1 = 0.2014	1.7847	26.10	
R_2 = + 12.9661				R_2 4.9642
	D_2 = 0.8928	1.51507	56.35	
R_3 = − 5.8567				R_3 4.9814
	S_1 = 0.0045			
R_4 = + 16.2336				R_4 4.8164
	D_3 = 0.3661	1.7170	47.90	
R_5 = − 22.5012				R_5 4.8014
	S_2 = 0.0045			
R_6 = + 5.6034				R_6 4.4335
	D_4 = 0.4241	1.7170	47.90	
R_7 = + 24.5154				R_7 4.3867
	S_3 = variable			
R_8 = + 3.9647				R_8 2.4286
	D_5 = 0.0804	1.69734	56.19	
R_9 = + 1.7362				R_9 2.1161
	S_4 = 0.5178			
R_{10} = − 3.9138				R_{10} 2.1018
	D_6 = 0.0714	1.69734	56.19	
R_{11} = + 4.4458				R_{11} 2.0132
	D_7 = 0.3036	1.7847	26.10	
R_{12} = − 4.4458				R_{12} 1.9925
	D_8 = 0.0714	1.69734	56.19	
R_{13} = + 8.2572				R_{13} 1.9161
	S_5 = variable			
R_{14} = − 1.8601				R_{14} 1.1153
	D_9 = 0.0536	1.69734	56.19	
R_{15} = + 1.8601				R_{15} 1.1721
	D_{10} = 0.1518	1.7847	26.10	
R_{16} = + 14.1274				R_{16} 1.1857
	S_6 = variable			
R_{17} = − 10.0095				R_{17} 1.2552
	D_{11} = 0.1875	1.5168	64.20	
R_{18} = − 1.9192				R_{18} 1.2861
	S_7 = 0.0045			
R_{19} = + 2.6841				R_{19} 1.3110
	D_{12} = 0.1875	1.5168	64.20	
R_{20} = − 10.8725				R_{20} 1.3033
	S_8 = 0.0045			
R_{21} = + 1.3446				R_{21} 1.2672
	D_{13} = 0.1875	1.5168	64.20	
R_{22} = + 2.9064				R_{22} 1.2220
	S_9 = 0.4375 (aspheric)			
R_{23} = − 4.2315				R_{23} 1.0500
	D_{14} = 0.3777	1.7283	28.66	
R_{24} = + 1.9174				R_{24} 0.9686
	S_{10} = 0.4714			
R_{25} = ∞				R_{25} 1.0019
	D_{15} = 0.0929	1.7283	28.66	
R_{26} = + 2.3366				R_{26} 1.0088
	D_{16} = 0.2304	1.61342	59.27	
R_{27} = − 2.3366				R_{27} 1.0186
	S_{11} = 0.0045			
R_{28} = + 5.7670				R_{28} 1.0068
	D_{17} = 0.2304	1.61342	59.27	
R_{29} = − 5.7670				R_{29} 0.9778

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TA S_3	TD S_5	TE S_6	TF F	TG log F
0.04318	3.63462	0.98730	1.00000	0.00
1.59156	2.01054	1.06300	1.77827	0.25
2.76329	0.86219	1.03962	3.16227	0.50
3.64395	0.23005	0.79109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

PS

CL

CL

Equation for aspheric surface R_{23}

$$x = -4.2315 + \sqrt{17.90559 - y^2} - 0.01666805\, y^4 + 0.02010843\, y^6 - 0.00176346\, y^6 - 0.00553820\, y^{10}$$

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Example III

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter
R_1 = − 7.2114				R_1 4.9192
	D_1 = 0.2014	1.7847	26.10	
R_2 = + 12.9661				R_2 4.9642
	D_2 = 0.8928	1.51597	56.35	
R_3 = − 5.8567				R_3 4.9814
	S_1 = 0.0045			
R_4 = + 16.2336				R_4 4.8164
	D_3 = 0.3661	1.7170	47.90	
R_5 = − 22.5012				R_5 4.8014
	S_2 = 0.0045			
R_6 = + 5.6034				R_6 4.4335
	D_4 = 0.4241	1.7170	47.90	
R_7 = + 24.5154				R_7 4.3867
	S_3 = variable			
R_8 = + 3.9647				R_8 2.4286
	D_5 = 0.0804	1.69734	56.19	
R_9 = + 1.7362				R_9 2.1161
	S_4 = 0.5176			
R_{10} = − 3.9318				R_{10} 2.1018
	D_6 = 0.0714	1.69734	56.19	
R_{11} = + 4.4458				R_{11} 2.0132
	D_7 = 0.3036	1.7847	26.10	
R_{12} = − 4.4458				R_{12} 1.9925
	D_8 = 0.0714	1.69734	56.19	
R_{13} = + 8.2572				R_{13} 1.9161
	S_5 = variable			
R_{14} = − 1.8601				R_{14} 1.1153
	D_9 = 0.0536	1.69734	56.19	
R_{15} = + 1.8601				R_{15} 1.1721
	D_{10} = 0.1518	1.7847	26.10	
R_{16} = + 14.1274				R_{16} 1.1857
	S_6 = variable			
R_{17} = ∞				R_{17} 1.2830
	D_{11} = 0.1911	1.524	58.87	
R_{18} = − 2.3322				R_{18} 1.3098
	S_7 = 0.0045			
R_{19} = + 10.6292				R_{19} 1.3238
	D_{12} = 0.1910	1.524	58.87	
R_{20} = − 10.6292				R_{20} 1.3288
	S_8 = 0.0045			
R_{21} = + 2.7812				R_{21} 1.3273
	D_{13} = 0.2678	1.61342	59.27	
R_{22} = − 2.7812				R_{22} 1.3060
	S_9 = 0.0100			
R_{23} = − 2.5142				R_{23} 1.3049
	D_{14} = 0.0893	1.72830	28.66	
R_{24} = ∞				R_{24} 1.2833
	S_{10} = 1.8928			
R_{25} = ∞				R_{25} 0.9600
	D_{15} = 0.0893	1.72830	28.66	
R_{26} = + 1.4266				R_{26} 0.9600
	S_{11} = 0.0298			
R_{27} = + 1.6477				R_{27} 0.9600
	D_{16} = 0.2929	1.69734	56.19	
R_{28} = − 2.7352				R_{28} 0.9600

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s_3	s_5	s_6	F	log F
0.04318	3.63462	1.0319	1.00000	0.00
1.59156	2.01054	1.1076	1.77827	0.25
2.76329	0.86219	1.08422	3.16227	0.50
3.64395	0.23005	0.83565	5.62339	0.75
4.23190	0.23796	0.23984	10.00000	1.00

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Example IV

Radius	Thickness or Air Separation	Refractive Index n_d	Abbe V Number	Clear Diameter	
R_1 = − 12.6240				R_1	8.6115
	D_1 = 0.3526	1.7847	26.10		
R_2 = + 22.6983				R_2	8.6903
	D_2 = 1.5630	1.51507	56.35		
R_3 = − 10.2525				R_3	8.7203
	S_1 = 0.0078				
R_4 = + 28.4181				R_4	8.4314
	D_3 = 0.6409	1.7170	47.90		
R_5 = − 29.3901				R_5	8.4052
	S_2 = 0.0078				
R_6 = + 9.8091				R_6	7.7612
	D_4 = 0.7425	1.7170	47.90		
R_7 = + 42.9160				R_7	7.6792
	S_3 = variable				
R_8 = + 6.9388				R_8	4.2516
	D_5 = 0.1407	1.69681	56.33		
R_9 = + 3.0368				R_9	3.7045
	S_4 = 0.9066				
R_{10} = − 6.8699				R_{10}	3.6795
	D_6 = 0.1250	1.69681	56.33		
R_{11} = + 7.8124				R_{11}	3.5240
	D_7 = 0.5314	1.78503	26.09		
R_{12} = − 7.8124				R_{12}	3.4870
	D_8 = 0.1250	1.69681	56.33		
R_{13} = + 14.3312				R_{13}	3.3528
	S_5 = variable				
R_{14} = − 3.2586				R_{14}	1.9539
	D_9 = 0.0938	1.69681	56.33		
R_{15} = + 3.2586				R_{15}	2.0536
	D_{10} = 0.2657	1.78503	26.09		
R_{16} = + 24.3322				R_{16}	2.0774
	S_6 = variable				
R_{17} = − 12.5098				R_{17}	2.2274
	D_{11} = 0.3345	1.65031	58.60		
R_{18} = − 3.7028				R_{18}	2.2899
	S_7 = 0.0078				
R_{19} = + 10.5352				R_{19}	2.3212
	D_{12} = 0.3345	1.65031	58.60		
R_{20} = − 10.5352				R_{20}	2.3181
	S_8 = 0.0078				
R_{21} = + 4.8649				R_{21}	2.2837
	D_{13} = 0.4689	1.61317	59.27		
R_{22} = − 4.8649				R_{22}	2.2259
	S_9 = 0.0258				
R_{23} = − 4.1260				R_{23}	2.2243
	D_{14} = 0.1563	1.7282	28.66		
R_{24} = + 27.3461				R_{24}	2.1602
	S_{10} = 2.8136				
R_{25} = ∞				R_{25}	1.7178
	D_{15} = 0.1563	1.76128	26.98		
R_{26} = + 1.8127				R_{26}	1.7350
	S_{11} = 0.0119				
R_{27} = + 1.8913				R_{27}	1.7382
	D_{16} = 0.5643	1.65031	58.60		
R_{28} = − 3.5367				R_{28}	1.7741
	S_{12} = 0.0078				
R_{29} = + 3.9463 (aspheric)				R_{29}	1.7554
	D_{17} = 0.2880	1.65031	58.60		
R_{30} = ∞				R_{30}	1.7100

TA S_3	TD S_5	TE S_6	TF F	TG log F
0.08428	6.36327	1.80704	1.00000	0.0
2.79513	3.51989	1.93956	1.77827	0.25
4.84654	1.50941	1.89864	3.16227	0.5
6.38837	0.40269	1.46352	5.62339	0.75
7.41774	0.41652	0.42032	10.00000	1.0

Equation for aspheric surface R_{29}

$$\underline{x} = + 3.9463 - \sqrt{15.57328 - \underline{y}^2} + 0.00427020\,\underline{y}^6$$
$$- 0.00777096\,\underline{y}^8 + 0.00721693\,\underline{y}^{10}$$

In all these examples, the maximum value F_m of the equivalent focal length F of the objective is ten times the minimum value F_o thereof. Example I is corrected for a relative aperture $\underline{f}/4.0$, whilst Examples II and III are each corrected for a relative aperture $\underline{f}/2.8$, and Example IV is corrected for a relative aperture of $\underline{f}/1.6$. Examples II and III differ from one another solely in the stationary rear member L_D, the front three members L_A, L_B and L_C being identical in the two examples. Such members L_A, L_B and L_C are in fact similar to the front three members L_A, L_B and L_C of Example I, the dimensions being scaled up from those of Example I in the ratio of the $\underline{f}$-numbers, that is in the ratio of 4.0/2.8. The rear members L_D in Examples II and III are, however, not scaled-up versions of the rear member L_D of Example I. The front three members L_A, L_B, L_C of Example IV, which includes yet another alternative

construction of rear member L_D, are of the same general type as those of Examples I – III, but their numerical dimensions differ somewhat from a version of those of Example I scaled up in the ratio 4.0/1.6.

All these examples cover a semi-angular field of view varying from 27 degrees at F_o to 2.7 degrees at F_m.

The iris diaphragm in all four examples is stationary and is located between the movable third member L_C and the stationary rear member L_D. In Example I the diaphragm is 0.0625 F_o in front of the surface R_{17} and has diameter 0.8568 F_o; in Example II the diaphragm is 0.0929 F_o in front of the surface R_{17} and has diameter 1.2240 F_o; in Example III the diaphragm is 0.1375 F_o in front of the surface R_{17} and has diameter 1.2240 F_o; and in Example IV the diaphragm is 0.2407 F_o in front of the surface R_{17} and has diameter 2.1446 F_o.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F_o in Example I, 2.6761 F_o in Example II, 2.3027 F_o in Example III and 1.7878 F_o in Example IV.

The equivalent focal length f_A of the stationary first member L_A is + 4.4551 F_o in Example I, + 6.3644 F_o in Examples II and III and + 11.1415 F_o in Example IV; the equivalent focal length f_B of the movable second member L_B is - 1.4703 F_o in Example I, - 2.1004 F_o in Examples II and III and - 3.6770 F_o in Example IV; the equivalent focal length f_C of the movable third member L_C is - 1.8176 F_o in Example I, - 2.5966 F_o in Examples II and III and - 4.5458 F_o in Example IV; and the equivalent

focal length f_D of the stationary fourth member L_D is $+ 1.4753\ F_o$ in Example I, $+ 2.1286\ F_o$ in Example II, $+ 2.3232\ F_o$ in Example III and $+ 4.0419\ F_o$ in Example IV; the positive and negative signs respectively indicating convergence and divergence.

In all four examples, the convergent stationary front member L_A consists of a meniscus doublet component followed by two convergent simple components. The front surface R_1 of the doublet component is concave to the front and has dispersive optical power numerically equal to $0.155/F_o$ or $0.692/f_A$ in Example I, to $0.109/F_o$ or $0.692/f_A$ in Examples II and III, and to $0.062/F_o$ or $0.692/f_A$ in Example IV. The internal contact R_2 of the doublet component is dispersive and convex to the front and has radius of curvature equal to $2.037\ f_A$ in all four examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is 0.27 in all four examples.

The combined equivalent focal length of the two simple components of the first member L_A is $4.0013\ F_o$ in Example I, $5.7162\ F_o$ in Examples II and III, and $10.0064\ F_o$ in Example IV or $0.8981\ f_A$ in all four examples. The radius of curvature R_4 of the front surface of the first of such simple components is $2.551\ f_A$ in all four exampl-s, and the radius of curvature R_6 of the front surface of the second of such simple components is $0.880\ f_A$ in all four examples. The rear surface R_7 of such second simple component is convex to the front with radius of curvature $3.852\ f_A$ in all four examples.

The axial thickness $(D_1 + D_2)$ of the meniscus

doublet component of the first member L_A is 0.766 F_o in Example I, 1.094 F_o in Examples II and III, and 1.916 F_o in Example IV, or 0.172 f_A in all four examples. The sum of the axial thicknesses of the two simple components ($D_3 + D_4$) of the first member is 0.553 F_o in Example I, 0.790 F_o in Examples II and III, and 1.383 F_o in Example IV, or 0.124 f_A in all four examples.

The arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member L_A in all four examples is 50.72 and thus exceeds the Abbe V number of the material of the divergent front element by 24.62.

The maximum value of the ratio of the equivalent focal length of the objective to the f-number of the objective is 2.5 F_o in Example I, 3.57 F_o in Examples II and III, and 6.25 F_o in Example IV, so that in all four examples f_A is 1.782 times such maximum value.

In all four examples, the minimum separation between the movable second and third members L_B and L_C occurs when the equivalent focal length of the objective is 7.45 F_o, and the numerical values of the equivalent focal lengths f_B and f_C of such members are respectively 5.88 and 7.27 times the minimum value of the ratio of the equivalent focal length of the objective to the f-number of the objective.

The movable second member L_B in all four examples consists of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent

element between two divergent elements, and its total axial movement (a unidirectional rearward movement) in the range of variation is numerically equal to 1.994 f_B. The front and rear surfaces R_8 and R_9 of the simple meniscus component of such member respectively have radii of curvature numerically equal to 1.89 f_B and 2.83 f_B in all four examples, whilst the front and rear surfaces R_{10} and R_{13} of the triplet component respectively have radii of curvature numerically equal to 1.86 f_B in Examples I to III and 1.87 f_B in Example IV and to 3.93 f_B in Examples I to III and 3.99 f_B in Example IV.

The moveable third member L_C in all four examples consists of a doublet component, whose front surface R_{14} is concave to the front with radius of curvature numerically equal to 0.72 f_C, and the total axial movement (the numerical sum of an initial forward movement plus a subsequent rearward movement) of such member is numerically equal to 0.363 f_C. The internal contact R_{15} of such doublet component is collective and convex to the front, with radius of curvature numerically equal to 0.72 f_C. The difference between the mean refractive indices of the materials of such doublet component is 0.087 in Examples I to III and 0.088 in Example IV, the difference between their Abbe V numbers being 30.09 in Examples I to III and 30.24 in Example IV.

In all four examples, the various aberrations are well stabilized in the front three members L_A, L_B, L_C throughout the range of variation of equivalent focal length of the objective and also throughout the focussing range, and the stationary rear member L_D serves to balance

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out such residual stabilised aberrations, and also to locate the resultant image plane in a convenient position. The construction of such rear member may thus vary widely.

In Examples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilised aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R_{23} of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and coma with minimum effect on oblique aberrations.

In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no aspheric surface is used in the actual example given,

some further improvement in aberration correction could be achieved by incorporating such a surface.

Yet another alternative construction for the stationary rear member L_D is employed in Example IV, consisting of seven simple components, the first three and the last two being convergent, and the fourth and fifth divergent. An aspheric surface is again used, in this case the front surface R_{25} of the rearmost component.

It is often desired in practice to provide two different ranges of variation of the equivalent focal length of the objective, and with the objective according to the present invention this can be carried out in a simple way by the provision of an achromatic doublet component, which can be placed at will behind the stationary rear member L_D of the objective, such doublet component, when in position, acting to move the resultant image plane further from the rear surface of the member L_D and to increase the values of the equivalent focal length of the objective in the same proportion throughout the range. Another effect of the addition of this doublet component is to reduce the relative aperture of the objective and the angular field covered. Numerical data are given below of two alternative examples of achromatic doublet component suited to follow the rear member L_D of Example I above. Figures 5 and 6 respectively show these two examples of doublet component L_E in position behind the main objective, which for simplicity is shown only in skeleton form, the front and rear surfaces only being shown for each of the four members L_A, L_B, L_C and L_D of the objective.

Example V

Radius	Thickness or Air Separation	Refractive Index $\underline{n_d}$	Abbe V Number	Clear Diameter
	$S_{11} = 0.2812$			
$R_{28} = \infty$	$D_{17} = 0.0781$	1.70035	30.28	R_{28} 0.7312
$R_{29} = -2.0920$	$D_{18} = 0.0500$	1.60483	43.83	R_{29} 0.7312
$R_{30} = +3.3428$				R_{30} 0.7312

Example VI

Radius	Thickness or Air Separation	Refractive Index $\underline{n_d}$	Abbe V Number	Clear Diameter
	$S_{11} = 0.7369$			
$R_{28} = \infty$	$D_{17} = 0.0781$	1.70035	30.28	R_{28} 0.6749
$R_{29} = -2.0920$	$D_{18} = 0.0500$	1.60982	53.31	R_{29} 0.6749
$R_{30} = +2.0920$				R_{30} 0.6749

The dimensions in these two examples of achromatic doublet component are given in terms of the minimum value F_o of the equivalent focal length for the objective of Example I. In each table S_{11} represents the air separation between the rear surface R_{27} of the stationary rear member L_D of Example I and the front surface R_{28} of the added doublet component. The doublet component in each case consists of a convergent element in front of a divergent element.

The added doublet component L_E of Example V increases the values of the equivalent focal length in the ratio 3:2, so that the normal range from F_o to 10 F_o is altered by the doublet component into a range from 1.5 F_o to 15 F_o. The doublet component of Example VI acts to double the values of the equivalent focal length of

Example I, thus giving a range from $2 F_o$ to $20 F_o$ when the doublet component is in position.

The back focal distance from the rear surface R_{30} of the added doublet component L_E to the new position of the resultant image plane is $3.704 F_o$ in Example V and $4.028 F_o$ in Example VI. The relative aperture of the objective is changed from f/4.0 by the addition of the doublet component to f/6.0 in Example V and f/8.0 in Example VI. The semi-angular field, which for Example I alone varies from 27 degrees at F_o to 2.7 degrees at F_m, varies (when the doublet component of Example V is added) from 18 degrees at $1.5 F_o$ to 1.8 degrees at $15 F_o$, and (when the doublet component of Example VI is added) from 13.5 degrees at $2 F_o$ to 1.35 degrees at $20 F_o$.

It will be realised that the addition of only an achromatic doublet component to an already well-corrected objective must necessarily result in a lower standard of aberration correction when the doublet component is in place. But the increased equivalent focal length and reduced relative aperture and angular field do not call for so high a standard of correction as is needed when the objective is used alone, and for many practical purposes the standard of correction obtained with the doublet component added is adequate.

The necessary axial movement of the second and third members may be brought about in various ways, for example by means of two appropriately shaped cams, which may be in the form of cam grooves B and E on the inner surface of a tubular member C rotated by the zoom

control element O and surrounding the second and third members M and H, which are held against rotation relatively to the fixed casing F of the objective. The focussing movement of the front member P may be effected under the control of a focussing control element O by mounting the front member in screw threaded engagement with the fixed casing F of the objective.

It will be appreciated that the foregoing examples have been given by way of example only and that the invention can be carried into practice in other ways.

WE CLAIM

1. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane), corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, said objective having a maximum equivalent focal length at least six times its minimum focal length, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_B lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_C lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_B$ and $2.5f_B$ and the total axial movement of the third member in the range lies numerically between $0.25f_C$ and $0.5f_D$, the minimum axial separation between the second and third member occurring when the equivalent focal length of the

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objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front. ~~with radius of curvature lying numerically between 0.5f_B and 1.0f_B.~~

2. An optical objective as claimed in claim 1, in which the compound component in the divergent movable second member includes at least one convergent element and at least one divergent element made of materials of differing ~~whose~~ Abbe V numbers ~~differ by more than 25~~.

~~3. An optical objective as claimed in claim 2, in which the radii of curvature of the front and rear surfaces of the simple meniscus component of the second member respectively lie numerically between 1.5f_B and 3f_B and between 0.66f_B and f_B.~~

3 ~~4~~. An optical objective as claimed in claim ~~3~~ 2, in which the front surface of the compound component of the second member is concave to the front and ~~with radius of curvature lying numerically between 1.5f_B and 3f_B, and~~ the rear surface of such component is convex to the front. ~~with radius of curvature lying numerically between 3f_B and 6f_B.~~

4 ~~5~~. An optical objective as claimed in claim ~~4~~ 3, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements. ~~the materials of the elements of such component having mean refractive indices differing~~

by less than 0.15 from one another, the materials of all the elements of the second member having mean refractive indices greater than 1.65 and being such that the arithmetic mean between the Abbe V numbers of the materials of the divergent elements exceeds that of the convergent element by at least 25.

5 ~~6~~. An optical objective as claimed in claim 4, in which the doublet component constituting the third member has a collective internal contact convex to the front. with radius of curvature lying numerically between $0.5f_C$ and f_C, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each greater than 1.65 and differ by between 0.05 and 0.15.

6 ~~7~~. An optical objective as claimed in claim 2, in which the front surface of the compound component of the second member is concave to the front and ~~with radius of curvature lying numerically between $1.5f_B$ and $3f_B$, and~~ the rear surface of such component is convex to the front. ~~with radius of curvature lying numerically between $3f_B$ and $6f_B$~~

7 ~~8~~. An optical objective as claimed in claim 2, in which the doublet component constituting the third member has a collective internal contact convex to the front, ~~with radius of curvature lying numerically between $0.5f_C$~~ and ~~f_C~~, the materials of the two elements of such component having differing Abbe V numbers ~~which differ by more than 25~~ and differing mean refractive indices. ~~which are each greater than 1.65 and differ by between 0.05 and 0.15.~~

8 ~~9~~. An optical objective as claimed in claim 1, in

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which the front surface of the compound component of the second member is concave to the front ~~with radius of curvature lying numerically between 1.5f_B and 3f_B, and~~ and the rear surface of such component is convex to the front. ~~front with radius of curvature lying numerically between 3f_B and 6f_B.~~

~~10. An optical objective as claimed in claim 9, in which the radii of curvature of the front and rear surfaces of the simple meniscus component of the second member respectively lie numerically between 1.5f_B and 3f_B and between 0.66f_B and f_B.~~

9 ~~11~~. An optical objective as claimed in claim 8 ~~9~~, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements, ~~the materials of the elements of each component having mean refractive indices differing by less than 0.15 from one another,~~ the materials of all the elements of the second member having mean refractive indices greater than 1.69 ~~1.65~~ and being such that the arithmetic mean between the Abbe V numbers of the materials of the divergent elements exceeds that of the convergent element ~~by at least 25~~.

10 ~~12~~. An optical objective as claimed in claim 9 ~~11~~, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

~~13. An optical objective as claimed in claim 1, in which the radius of curvature of the front surface of~~

~~the simple meniscus component of the second member lies numerically between $1.5\underline{f}_B$ and $3\underline{f}_B$.~~

~~14. An optical objective as claimed in claim 1, in which the radius of curvature of the rear surface of the simple meniscus component of the second member lies numerically between $0.66\underline{f}_B$ and $\underline{f}_B$.~~

11 ~~15.~~ An optical objective as claimed in claim 1, in which the compound component of the second member consists of a triplet component having a convergent element between two divergent elements.

~~16. An optical objective as claimed in claim 15, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5\underline{f}_C$ and $\underline{f}_C$, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each greater than 1.65 and differ by between 0.05 and 0.15.~~

~~17. An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature lying numerically between $0.5\underline{f}_C$ and $\underline{f}_C$, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbe V numbers of such materials exceeds 25.~~

14 ~~18.~~ An optical objective as claimed in claim ~~17~~ 13, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective

and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

15. An optical objective of the zoom type (that is of the type having relatively movable members whereby the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane), corrected for spherical and chromatic aberrations, coma, astigmatism, field curvature and distortion, and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length f_B lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length f_C lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between $1.5f_B$ and $2.5f_B$ and the total axial movement of the third member in the range lies numerically between $0.25f_C$ and $0.5f_C$, the minimum axial separation between the second and third members occurring when the

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equivalent focal length of the objective is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, the movable divergent third member consisting of a doublet component having its front surface concave to the front, ~~with radius of curvature lying numerically between $0.5f_C$ and $1.0f_C$,~~ and the first member of the objective comprises a meniscus doublet component having a front surface which is concave to the front and ~~has dispersive optical power lying numerically between $0.5/f_A$ and $1.0/f_A$ (where f_A is the equivalent focal length of the first member) and~~ two simple convergent components behind such meniscus doublet component.

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~~20.~~ 16. An optical objective as claimed in claim ~~19~~ 15, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front, ~~with radius of curvature between $1.5f_A$ and $3f_A$,~~ the difference between the mean refractive indices of the materials of the two elements of the doublet being greater than 0.15 and in which the arithmetic mean between the Abbe V numbers of the materials of the three convergent elements of the first member exceeds by at least 20 the Abbe V number of the material of the divergent front element of the meniscus doublet component of the first member.

~~21.~~ 17. An optical objective as claimed in claim ~~20~~ 16, in which the compound component in the divergent movable

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second member includes at least one convergent element and at least one divergent element, and the ~~made of materials whose Abbe V numbers differ by more than 25, and the~~ doublet component constituting the third member has a collective internal contact convex to the front. ~~with radius of curvature lying numerically between $0.5f_C$ and f_C, the materials of the two elements of such component having Abbe V numbers which differ by more than 25 and mean refractive indices which are each greater than 1.65 and differ by between 0.05 and 0.15.~~

18. An optical objective as claimed in claim ~~15~~ 15, in which the two simple components of the first member together ~~have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$, and~~ have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being ~~less than $4f_A$ and~~ greater than twice the radius of curvature of the front surface of the second of such simple components, the rear ~~which latter radius of curvature is in turn greater than $0.75f_A$, the rear~~ surface of the second of the two simple components being convex to the front. ~~with radius of curvature between $2f_A$ and $7f_A$.~~

~~23. An optical objective as claimed in claim 22, in which the radii of curvature of the front and rear surfaces of the simple meniscus component of the second member respectively lie numerically between $1.5f_B$ and $3f_B$ and between $0.66f_B$ and f_B.~~

19. An optical objective as claimed in claim 15, in which the axial thickness of the meniscus doublet

a component of the first member is ~~less than 0.25f_A and~~ is greater than the sum of the axial thicknesses of the

a two simple components of the first member, ~~such sum in turn~~ being greater than $0.075f_A$, the equivalent focal length f_A ~~of~~ the first member lying between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f-number ~~of the~~ objective in the range of variation.

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20. An optical objective as claimed in claim 19, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

21. An optical objective as claimed in claim 15, including an achromatic doublet which can be placed at will behind the stationary rear member of the objective and acts when in its operative position to increase the values of the equivalent focal length of the objective by a chosen ratio throughout the range of variation.

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~~27. An optical objective as claimed in claim 26, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front with radius of curvature between $1.5f_A$ and $3f_A$, the difference between the mean refractive indices of the materials of the two elements of the doublet being greater than 0.15.~~

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DECLARATION, PETITION AND POWER OF ATTORNEY

We, GORDON HENRY COOK and PETER ARNOLD MERIGOLD declare that we are ~~citizens of~~ both Subjects of the Queen of England ~~respectively~~, and residents of Oadby, County of Leicester, England; and Prestatyn, County of Flintshire, Wales, United Kingdom, respectively; that we have read the foregoing specification and claims, that we verily believe ourselves to be the original, first and joint inventors of the improvement in OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH described and claimed in the foregoing specification; that this application in part discloses and claims subject matter disclosed in our earlier filed pending application Serial No. 309,208, filed September 16, 1963, that as to to subject matter of this application which is common to said earlier application we do not know and do not believe that the same was ever known or used before our invention thereof or patented or described in any printed publication in any country before our invention thereof or more than one year prior to said earlier application, or in public use or on sale in the United States more than one year prior to said earlier application; that said common subject matter has not been patented before the date of said earlier application in any country foreign to the United States on an application filed by us or our legal representatives or assigns more than twelve months prior to said application; and that the earliest application for patent on said invention filed by us or our legal representatives

or assigns in any country foreign to the United States was:

Great Britain - No. 35088 filed Sept.14,1962

that as to the subject matter of this application which is not common to said earlier application, we do not know and do not believe that the same was ever known or used before our invention thereof or patented or described in any printed publication in any country before our invention thereof or more than one year prior to the date of this application, or in public use or on sale in the United States more than one year prior to the date of this application, and that said subject matter has not been patented in any country foreign to the United States on an application filed by us or our legal representatives or assigns more than twelve months prior to the date of this application; and that no application for patent on said invention has been filed by us or our legal representatives or assigns in any country foreign to the United States.

And we declare further that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

And we hereby appoint HOLCOMBE, WETHERILL & BRISEBOIS, a firm having offices at Suite 307, Crystal Plaza Building No. 1, 2001 Jefferson Davis Highway, Arlington, Virginia 22202, Registration No. 17,348, our attorneys with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith.

Wherefore we pray that Letters Patent be granted to us for the invention or discovery described and claimed in the foregoing specification and claims, and we hereby subscribe our names to the foregoing specification and claims, declaration, power of attorney, and this petition,

(1) this 4th day of June, 1971.
(2) this 2nd day of June, 1971.

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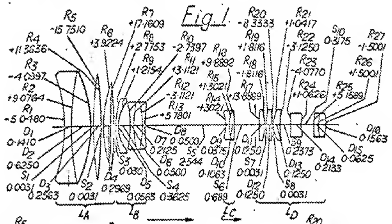

Fig. 1.

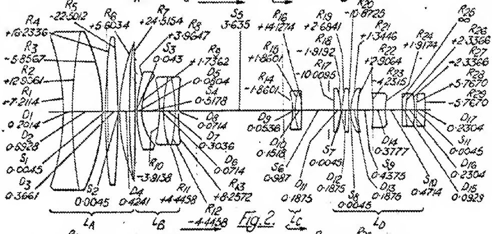

Fig. 2.

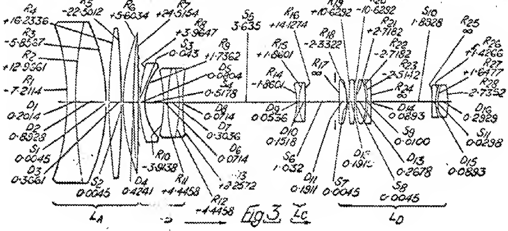

Fig. 3.

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Fig. 4.

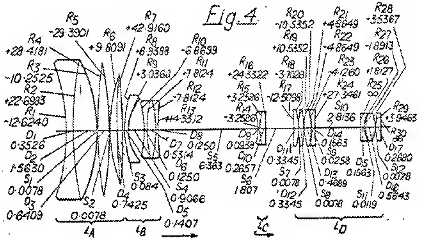

Fig. 5.

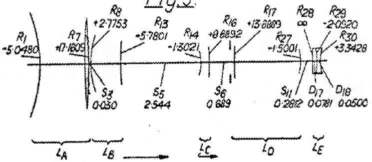

Fig. 6.

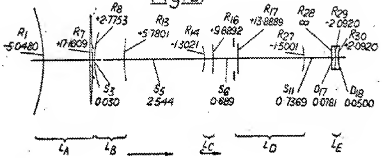

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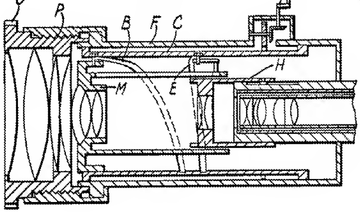
Fig. 7.



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Case Docket No. 7955

JUNE 11, 1971

THE COMMISSIONER OF PATENTS
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Sir:

Transmitted herewith for filing is the patent application of

Inventor: GORDON HENRY COOK & PETER ARNOLD MERIGOLD

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

This application is a continuation in part of SN 309,208

Enclosed are:

[X] 3 sheets of drawing. 2 sheets informal & 1 sheet formal

[X] An assignment of the invention to THE RANK ORGANISATION LIMITED

[ ] A certified copy of a ____________ application.

[ ] Associate power of attorney.

CLAIMS AS FILED

(1) FOR	(2) NUMBER FILED		(3) NUMBER EXTRA	(4) RATE	(5) BASIC FEE $65.00
TOTAL CLAIMS	27	-10*	17	X $2.00	34.00
INDEPENDENT CLAIMS	2	-1*	1	X $10.00	10.00
					20.00 Assignment
				TOTAL FILING FEE →	129.00

[ ] Please charge my Deposit Account No. ____________ in the amount of $__________. A duplicate copy of this sheet is enclosed.

[X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Account No. 08-2720. A duplicate copy of this sheet is enclosed.

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2001 JEFFERSON DAVIS HWY.
ARLINGTON, VIRGINIA.

PLEASE REFER TO THE FOLLOWING:	GROUP ART UNIT
APPLICANT (S) GORDON HENRY COOK, et. al.	
SERIAL NUMBER 152,254	FILING DATE 6-11-71
TITLE OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH	

NOTICE OF INSUFFICIENT FEE AND / OR INFORMAL DRAWINGS

Correction of the informality checked below is required.
APPLICANT IS GIVEN TWO (2) MONTHS WITHIN WHICH TO SUBMIT THE FORMAL DRAWINGS AND / OR FEE to avoid abandonment of the application.

1. ☐ The filing fee of $________ submitted in this application is insufficient.

   A balance of $________ is due for additional claims.

2. ☒ The photoprints submitted in lieu of formal drawings have been accepted for filing only (Rule 85).

   Formal drawings complying with Rule 84 together with the comparison fee of $10 (or authorization to use a deposit account) are required.

   The Drafting Division of the Patent Office does not have the facilities for preparing new drawings at the present time.

To ensure prompt processing and forwarding of the formal drawings to the examiner, each sheet should include the Serial Number and Group Art Unit in the upper right margin.

MAILED
NOV 24 1971
GROUP 250

P. Fisk
Head, Application Branch

lvw

FOR USE IN TRANSMITTING FORMAL DRAWINGS AND / OR FEE

Check the appropriate box below.

☐ Check for $________ enclosed.

☐ Charge $________ to my Deposit Account No.______. Two copies of this letter are enclosed.

The above is to cover the

☐ comparison fee.

☐ balance of filing fee due.

Please transmit the formal drawings and / or fee together with a copy of this form. BE SURE TO ADDRESS THE GROUP ART UNIT SHOWN ABOVE.

51

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al Exam

7955

#3

RECEIVED

DEC 9 1971

IN THE UNITED STATES PATENT OFFICE

GROUP 250

In re application of

December 2, 1971

GORDON HENRY COOK et al

GR 259

Serial No. 152,254

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

LETTER

Hon. Commissioner of Patents
Washington, D.C. 20234

Sir:

Responsive to the enclosed letter, please transfer from the file of the parent application, SN 309,208, filed September 16, 1967, (now abandoned), the two sheets of drawings in that case. These correspond to the two informal prints initially filed with the above-entitled application.

Respectfully submitted,

HOLCOMBE, WETHERILL & BRISEBOIS

521-1550

By Joseph F. Brisebois Reg. 15,965

52

U.S. DEPARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

J. K. Corbin Group 259

Paper No. 4

06/11/71 152-254
COOK, GORDON HENRY, ET. AL.

Mailed

HOLCOMBE, WETHERILL &
BRISEBOIS,
2001 JEFFERSON DAVIS HWY.,
SUITE 307,
ARLINGTON, VA. 22202

This is a communication from the Examiner in charge of your application.

Commissioner of Patents

☑ This application has been examined.

☐ Responsive to communication filed ______ ☐ This action is made final.

A SHORTENED STATUTORY PERIOD FOR RESPONSE TO THIS ACTION IS SET TO EXPIRE Three MONTH(S) ~~DAYS~~ FROM THE DATE OF THIS LETTER.

PART I

The following attachments(s) are part of this action:

a. ☑ Notice of References Cited, Form PO-892. b. ☐ Notice of Informal Patent Drawing, PO-948.

c. ☐ Notice of Informal Patent Application, Form PO-152. d. ☐

PART II

Summary of Action

1. ☑ Claims 1-27 are presented for examination.
2. ☐ Claims ______ are allowed.
3. ☐ Claims ______ would be allowable if amended as indicated.
4. ☑ Claims 1-27 are rejected.
5. ☐ Claims ______ are objected to.
6. ☐ Claims ______ are subject to restriction or election requirement.
7. ☐ Claims ______ are withdrawn from consideration.
8. ☐ Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 OG. 213.
9. ☐ Since it appears that a discussion with applicant's representative may result in agreements whereby the application may be placed in condition for allowance, the examiner will telephone the representative within about 2 weeks from the date of this letter.
10. ☐ Receipt is acknowledged of papers under 35 USC 119, which papers have been placed of record in the file.
11. ☐ Applicant's claim for priority based on an application filed in ______ on ______ is acknowledged. It is noted, however, that a certified copy as required by 35 USC 119 has not been received.
12. ☐ Other

54

POL 326 (10/70)

A separate letter to the Draftsman for correcting the curvature of R_7 to show that it is slightly convex to the front, as submitted in the parent case, should be submitted in the present case.

The Yamaji, Harris et al, and Klemt et al patents are cited to show the state of the art.

Claims 1-27 are rejected under 35 U.S.C. 112, first paragraph, as based on a disclosure which fails to establish the validity of the numerical ranges for certain of the lens parameters. The numerical embodiments in the specification clearly do not support the validity of the ranges. Further the explanation in the specification, pages 16-20, fails to explain most of the ranges set forth in the dependent claims. The explanation on pages 16-20, however, does appear to establish the truthfulness of the ranges in parent claim 1 except for the one in the last two lines. The reasoning set forth in In re Cook and Merigold 169 USPQ 298, and especially as set forth on page 303 is applicable to the last range in claim 1 and those in the dependent claims.

Allowable subject matter is consider present in the disclosure.

J. K. Corbin:vgr
703/557/3107
5-16-72

John K. Corbin
JOHN K. CORBIN
EXAMINER
GROUP ART UNIT 259

MAY 17 1972

TO SEPARATE: HOLD TOP AND BOTTOM EDGES, SNAP-APART AND DISCARD CARBON

ATTACHMENT TO PAPER NO. 4

FORM PO-892 (7-69)

U.S. DEPARTMENT OF COMMERCE PATENT OFFICE

NOTICE OF REFERENCES CITED

☐ Check here if this is a supplemental citation (Do not prepare an additional folder)

SERIAL NO. 152,254

GROUP ART UNIT 259

APPLICANT(S) Cook et al

U.S. PATENTS

	PATENT NO.	DATE	PATENTEE	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
1	3027805	4-1962	Yamaji	350	184	
2	3038378	6-1962	Harris et al (1)	350	186 X	
3	3057257	10-1962	Klemt et al (1)	350	184	
4						
5						
6						
7						
8						
9						
10						
11						

FOREIGN PATENTS AND SPECIFICATIONS *

	PATENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG.	PERTINENT PP. SPEC.
1								
2								
3								
4								
5								
6								

OTHER REFERENCES (Include author, title, date, pertinent pages, etc.)

EXAMINER John K. Corbin

DATE 5/10/72

☐ Check here if foreign exchange

* APPLICATIONS

56

U.S. DEPARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

HOLCOMBE, WETHERILL & BRISEBOIS
SUITE 307
CRYSTAL PLAZA BLDG.
2001 JEFFERSON DAVIS HWY.
ARLINGTON, VIRGINIA.

PLEASE REFER TO THE FOLLOWING:	GROUP ART UNIT
APPLICANT (S): GORDON HENRY COOK, et.al.	
SERIAL NUMBER 152,254	FILING DATE 6-11-71
OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH	

NOTICE OF INSUFFICIENT FEE AND / OR INFORMAL DRAWINGS

Correction of the informality checked below is required.
APPLICANT IS GIVEN TWO (2) MONTHS WITHIN WHICH TO SUBMIT THE FORMAL DRAWINGS AND / OR FEE to avoid abandonment of the application.

1. [ ] The filing fee of $________ submitted in this application is insufficient.

A balance of $________ is due for additional claims.

2. [X] The photoprints submitted in lieu of formal drawings have been accepted for filing only (Rule 85).

Formal drawings complying with Rule 84 together with the comparison fee of $10 (or authorization to use a deposit account) are required.

The Drafting Division of the Patent Office does not have the facilities for preparing new drawings at the present time.

To ensure prompt processing and forwarding of the formal drawings to the examiner, each sheet should include the Serial Number and Group Art Unit in the upper right margin.

MAILED
NOV 24 1971
GROUP 250

Head, Application Branch

lvw

FOR USE IN TRANSMITTING FORMAL DRAWINGS AND / OR FEE

Check the appropriate box below.

[ ] Check for $________ enclosed.

[ ] Charge $________ to my Deposit Account No.________. Two copies of this letter are enclosed.

The above is to cover the

[ ] comparison fee.

[ ] balance of filing fee due.

Please transmit the formal drawings and / or fee together with a copy of this form. BE SURE TO ADDRESS THE GROUP ART UNIT SHOWN ABOVE.

PO 1094
REV 3/71

USCOMM DC-60788 P71

NOV - 6 1972 - 3

MAIL ROOM NOV 6 1972 U.S. PATENT OFFICE

RECEIVED 7955

NOV 7 1972 11-9-2AD

GROUP 250 5/a

IN THE UNITED STATES PATENT OFFICE

In re application of	November 6, 1972
GORDON HENRY COOK et al	
Serial No. 152,254	Gr.Art Unit 259
Filed June 11, 1971	M Edge 11-18-72
For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH	Exr. J. K. Corbin

---

AMENDMENT

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

Responsive to Official Action mailed August 4, 1972, please amend the above-entitled application as follows:

Claim 1, next to last line, cancel "with radius" and substitute a period;

cancel the last line.

Claim 2, line 5, cancel "whose" and substitute --of differing--; cancel "differ by more than 25".

Cancel Claim 3.

Claim 4, line 1, cancel "3" and substitute --2--;

line 3, cancel "with radius of" and substitute --and--;

cancel line 4;

at the end of line 5 insert a period;

cancel lines 6 and 7.

57

Claim 5, line 4, cancel "the materials of the elements of" and substitute a period;

cancel lines 5-11 inclusive.

Claim 6, at the end of line 3 insert a period;

cancel lines 4-8 inclusive.

Claim 7, line 3, cancel "with radius of" and substitute --and--;

cancel line 4;

at the end of line 5 insert a period;

cancel lines 6 and 7.

Claim 8, at the end of line 3 insert a comma;

cancel line 4;

line 5, cancel "and f_C,";

line 6, after "having" insert --differing--; cancel "which differ by more than"'

line 7, cancel "25"; after "and" insert --differing--; cancel "which are each greater" and substitute a period;

cancel the last line.

Claim 9, line 3, cancel "with radius of" and substitute --and--;

cancel line 4;

at the end of line 5 insert --front.--;

cancel lines6 and 7.

Cancel Claim 10.

Claim 11, line 4, cancel "the materials of the elements of";

cancel line 5;

line 6, cancel "by less than 0.15 from one another";

Claim 11, line 8, cancel "1.65" and substitute --1.69--;
last line, cancel "by at least 25".

Cancel Claims 13 and 14.

Rewrite Claims 16 and 17 as follows:

--~~16~~ 12 (Amended) An optical objective as claimed in Claim 11 ~~15~~, in which the doublet component constituting the third member has a collective internal contact convex to the front with radius of curvature [lying numerically between $0.5f_C$ and f_C] substantially equal to $0.72f_C$, the materials of the two elements of such component having Abbe V numbers which differ by [more than 25] about 30 and mean refractive indices which are each greater than [1.65] 1.69 and differ by [between 0.05 and 0.15] about 0.09.

a'

~~17~~ 13. (Amended) An optical objective as claimed in claim 1, in which the doublet component constituting the divergent movable third member has a collective internal contact convex to the front with radius of curvature [lying numerically between $0.5f_C$ and f_C] substantially equal to $0.72f_C$, the difference between the mean refractive indices of the materials of the two elements of such component [lying between 0.05 and 0.15] being about 0.09, [whilst] while the difference between the Abbe V numbers of such materials [exceeds 25] is about 30.

Claim 19, line 35, cancel "with radius of" and substitute a comma;
cancel line 36;
line 39, cancel "has dispersive optical power";
cancel lines 40 and 41.

59

Claim 20, cancel line 4, and substitute --to the front.--;

cancel lines 5-12 inclusive.

Claim 21, line 4, cancel "made of materials" and substitute --, and the--;

cancel line 5;

line 7, cancel "with" and substitute a period;

cancel lines 8-12 inclusive.

Claim 22, cancel line 3 and substitute --together--;

line 4, cancel "between 0.75f_A and 1.25f_A, and";

line 7, cancel "less than 4f_A and";

line 9, cancel "which latter radius" and substitute --the rear--;

cancel line 10;

line 12, cancel "with radius of curvature" and substitute a period;

cancel the last line.

Cancel Claim 23.

Claim 24, line 3, cancel "less than 0.25f_A and";

line 5, cancel ", such sum in" and substitute a period;

cancel lines 6-10 inclusive.

Rewrite Claim 27 as follows:

--~~27~~ 22 (Amended) An optical objective as claimed in claim ~~26~~ 21, in which the internal contact of the meniscus doublet component of the first member is dispersive and convex to the front with radius of curvature [between 1.5f_A and 3f_A] substantially equal to 2.04f_A, the difference between the mean refractive indices of the materials of the two elements of the doublet being [greater than 0.15] substantially 0.27.--

a2

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REMARKS

The criticized range in the last two lines of Claim 1 has been eliminated, since the approximate curvature of the front surface of the third member may be deduced by a skilled lens designer to lie within this range, once he has been given the basic information contained earlier in the claim.

The dependent claims have likewise been amended to eliminate unsubstantiated ranges.

The required letter to the Official Draftsman is attached hereto.

Since none of the references were applied to the claims, the application is now presumed to be in condition for allowance.

Respectfully submitted,

GORDON HENRY COOK et al

By [signature]
Joseph F. Brisebois Reg.15,965
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
JFB:gw

NOV - 6 1972 -8

MAIL ROOM NOV 6 1972 U.S. PATENT OFFICE

RECEIVED 1492 #6

NOV 7 1972 7955

GROUP 250

IN THE UNITED STATES PATENT OFFICE

In re application of November 6, 1972

GORDON HENRY COOK et al

Serial No. 152,254 Gr.Art Unit 259

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH Exr. J. K. Corbin

Approved 11/21/72 JKC

LETTER TO OFFICIAL DRAFTSMAN

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

Please correct the surface R_7 in each of Figures 1-6 to show it as slightly convex to the front, as indicated in red on the attached prints, and charge the cost of this work to our Miscellaneous Account No. 08-2720, Order No. 53.

Respectfully submitted,

GORDON HENRY COOK et al

By [signature]
Joseph F. Brisebois Reg.15,965
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
JFB:gw

CORRECTED
NOV 22 1972
PHOTOCOPIES MAILED

62

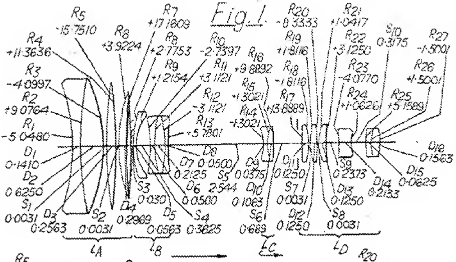


Fig. 1.

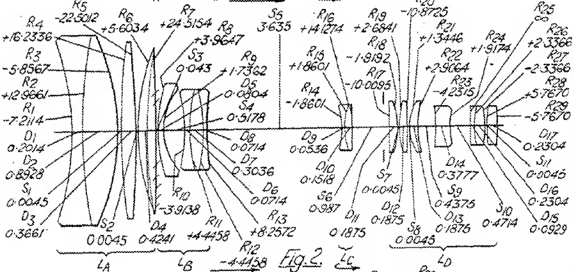


Fig. 2.

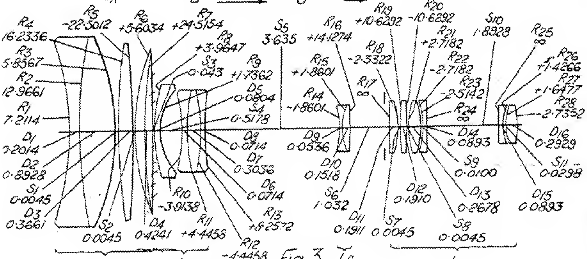


Fig. 3.

Sn 153,254 p. 259 L3

Fig. 4

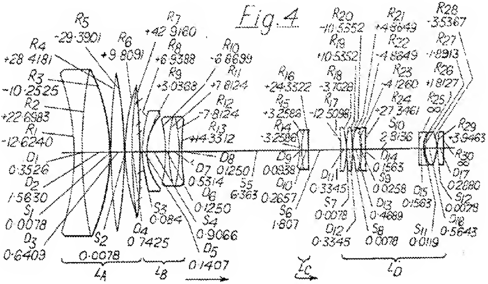


Fig. 5

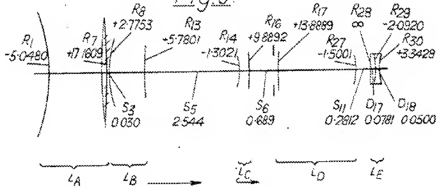
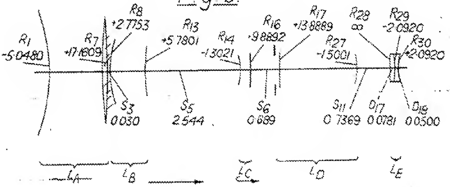


Fig. 6



Sn 152 214 fr 259 64

U.S. DEPARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

N. Edge
11-21-72

In Reply Please Refer To The Following:

EXAMINER'S NAME J. K. Corbin		
259	June 11, 1971	152,254
GR. ART UN.	FILING DATE	SERIAL NO.

Gordon Henry Cook et al

APPLICANT — INVENTION

OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Paper No. 7/B

Mailed

DEC 20 1972

GROUP 250

Holcombe, Wetherill, & Brisebois
2001 Jefferson Davis Hwy., Suite 307
Arlington, Va. 22202

Please find below a communication from the EXAMINER in charge of this application.

Commissioner of Patents

CHANGES AND/OR ADDITIONS TO THE APPLICATION RECORD MADE BY THE EXAMINER UPON ALLOWANCE

This application is in condition for allowance and the following changes have been made therein by the Examiner. Should the changes be unacceptable to applicant, an appropriate amendment may be proposed *after the Notice of Allowance has been received, as provided under Rule 312.* To ensure consideration of such an amendment, it must be submitted on or before remittance of the Base Issue Fee.

PROSECUTION ON THE MERITS IS CLOSED. A NOTICE OF ALLOWANCE WILL BE MAILED IN DUE COURSE.

[ ] Note attached Notice of References Cited, PO-892, which is part of this communication. The listed references are considered to be pertinent to the claimed invention, but the claims are deemed patentable thereover.

In line 8 of page 3 ---, now abandoned--- been inserted after "1963".

J. K. Corbin:sas

703/557/3107

11-17-72

John K. Corbin

JOHN K. CORBIN
EXAMINER
GROUP ART UNIT 259

PLEASE FURNISH YOUR ZIP CODE IN ALL CORRESPONDENCE

FORM POL-37 (REV. 3/70)

POL-85
(REV. 10.70)

All communications regarding this application should give the serial number, date of filing, and name of the applicant.

U.S. DEPARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

NOTICE OF ALLOWANCE AND BASE ISSUE FEE DUE

The application identified below has been examined and found allowable for issuance of Letters Patent.

	FILING DATE	SERIAL NO.	NO. OF CLAIMS ALLOWED	EXAMINER AND GROUP ART UNIT
	06/11/71	152254	22	Corbin 259
APPLICANT(S)	Cook, Gordon Henry; England, and Merigold, Peter Arnold; Wales			MAILED Jan. 10, 1973 mlb
TITLE OF INVENTION (X indicates as amended by examiner)	Optical objectives of variable equivalent focal length			
BASE FEE COMPUTATION			BASE FEE DUE	CLASS-SUB
$100.00	+ $6 (FOR DWG. @ $2 PER SHEET)	+ $10 (FOR FIRST PAGE PRINTED SPEC.)	$116	350/186.000

The complete Issue Fee is one hundred dollars ($100) plus two dollars ($2) for each sheet of drawing, plus ten dollars ($10) for each printed page of specification (including claims) or portion thereof.

Inasmuch as the final number of printed pages cannot be determined in advance of printing, an initial BASE ISSUE FEE (consisting of the fee for printing the first page of specification ($10) plus the fee of ($2) for each sheet of drawing, added to the fee of $100) *must be paid within three months from the date of this notice*, or the application shall be regarded as ABANDONED.

When remitting said Base Issue Fee, enclosed Form POL-85b should be used, and if use of a Deposit Account is being authorized, POL-85c should also be forwarded.

The Base Issue Fee will not be accepted from anyone other than the applicant, his assignee, attorney, or a party in interest as shown by the records of the Patent Office.

If an assignment has not been previously filed and it is desired to have the patent issue to the assignee, the assignment must be received in this Office with the recording fee together with the Base Issue Fee. In any event, the appropriate space(s) under "Assignment Data" on POL-85b must be completed. Where there is an assignment, the assignee's address must be given to ensure its inclusion in the printed patent.

In connection with the address of the inventor(s), attention is directed to Form POL-231 enclosed.

A Notice of Balance of Issue Fee Due will be mailed together with the patentee's copy of the patent *if an additional fee is due*. Payment must be made within three months from the date shown on said Notice since FAILURE TO PAY THIS BALANCE WITHIN THE TIME SPECIFIED WILL RESULT IN LAPSE OF THE PATENT.

Holcombe, Wetherill, et al
2001 Jefferson Davis Hwy.,
Suite 307
Arlington, Va. 22202

IMPORTANT

ATTENTION IS DIRECTED TO RULE 334 REVISED NOVEMBER 4, 1969.

THE PATENT WILL ISSUE TO APPLICANT UNLESS AN ASSIGNEE IS SHOWN IN ITEM 2 ON FORM POL-85b, ATTACHED

PATENT OFFICE COPY

66

BEST COPY

POL-85b (REV. 10/79) MAR - 9 1973 -24 100 — 10 — 6 — B U.S. Department of Commerce Patent Office

MAIL ROOM MAR 9 1973

BASE ISSUE FEE TRANSMITTAL

KEYED

This form is provided in lieu of a formal transmittal and should be used for transmitting the Base Issue Fee. Items numbered 1 through 4 below should be completed where appropriate. The Base Issue Fee Receipt will be mailed to the address appearing in item 4 or as designated in item 4a below.

1. The COMMISSIONER OF PATENTS is requested to apply the Base Issue Fee to the application identified below and deliver the patent as indicated.

March 9, 1973 (DATE) — Holcombe Wetherill & Brisebois (SIGNATURE OF PARTY IN INTEREST OF RECORD)

PRIORITY DOCUMENTS ATTACHED

NOTE: The Base Issue Fee will not be accepted from anyone other than the applicant, his assignee, or attorney, or a party in interest as shown by the records of the Patent Office, nor will this fee be accepted in the application prior to the Notice of Allowance.

	FILING DATE	SERIAL NO.	NO. OF CLAIMS ALLOWED	EXAMINER AND GROUP ART UNIT
	06/11/71	152254	22	Corbin 259
APPLICANT(S)	Cook, Gordon Henry; England, and Marigold, Peter Arnold; Wales			MAILED Jan. 10, 1973 mlb
TITLE OF INVENTION (X indicates as amended by examiner)	Optical objectives of variable equivalent focal length			NOTICE OF ALLOWANCE DATE

BASE FEE COMPUTATION				BASE FEE DUE	CLASS-SUB
$100.00	+ 06 (FOR DWG @ $2 PER SHEET)	+ $10	(FOR FIRST PAGE PRINTED SPEC.)	$116	350/186.000

2. ASSIGNMENT DATA (print or type)

A. The appropriate box(es) in this item MUST be checked:

(1) This application is NOT assigned;

(2) xx This application IS assigned;

(3) Assignment herewith;

(4) xx Assignment recorded and returned by Patent Office:

xx YES NO

B. For printing on the patent: (Unless an assignee is identified below, the patent will issue to the applicant above-named. Completion of this item, however, is NOT a substitute for filing the assignment as required in Rule 334)

(1) NAME OF ASSIGNEE:

THE RANK ORGANISATION LIMITED

(2) ADDRESS: (City & State or Country)

London, England

(3) STATE OF INCORPORATION, IF ASSIGNEE IS A CORPORATION: England

3. BASE FEE ENCLOSED

x YES NO

Charge to my Deposit Account Number: (POL-85c must be enclosed)

a. For Base Fee

b. For Balance of Issue Fee Due, if any.

c. For Recording Enclosed Assignment.

DO NOT USE THIS SPACE

03/15/73	152254	106 2	100.00 CK
03/15/73	152254	107 2	10.00 CK
03/15/73	152254	108 2	6.00 CK

MAILING INSTRUCTIONS

NOTE: All further correspondence, the patent together with the Notice of Balance of Issue Fee Due, if any, will be mailed to the addressee entered in the stub marked 4 at the lower left below, unless you direct otherwise by specifying the appropriate name and address in item 4a below right.

4a. Further correspondence is to be mailed to the following:

93

MAR - 9 1973 -24

7955 #8

MAIL ROOM MAR 9 1973 U.S. PATENT OFFICE

IN THE UNITED STATES PATENT OFFICE

In re application of

GORDON HENRY COOK et al

Serial No. 152,254

Filed June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

March 9, 1973

Alld. Jan.10,1973

Final Fee Pd. Mar.9,1973

Gr. Art Unit 259

Exmr. Corbin

CLAIM OF PRIORITY

Honorable Commissioner of Patents
Washington, D.C. 20231

Sir:

Applicants hereby claim the priority of their corresponding British application No. 35088 filed in Great Britain, September 14, 1962 by applicants' assignee RANK PRECISION INDUSTRIES LIMITED trading as THE RANK ORGANISATION RANK TAYLOR HORSON DIVISION as is permitted by British law, applicants being the true and first inventors.

A certified copy of said British application is attached.

Please note that this application is a continuation-in-part of application Serial No. 309,208, filed September 16, 1963.

Respectfully submitted,

GORDON HENRY COOK et al

By Joseph F. Brisebois
Joseph F. Brisebois Reg.No. 15,965
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
dkf

67

SN 152,254 1955
GR 259

THE PATENT OFFICE,
25 SOUTHAMPTON BUILDINGS,
LONDON.

I, the undersigned, being an officer duly authorised in accordance with Section 62(3) of the Patents and Designs Act, 1907, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of documents as originally filed in connection with the Patent application identified therein.

WITNESS my hand this
9th day of February 1973

68

COC. 1

6246 D.185353 40M 1/71 T.P. Gp 658

14 SEPT 1962

Patents Form No. 1

FEE STAMP

Adhesive stamps should not be used

No. 35088 1962

VI

THIS SPACE FOR OFFICE USE ONLY

35086

PATENTS ACT, 1949

APPLICATION FOR PATENT

(To be accompanied by two copies of Patents Form No. 2 or of Patent Form No. 3)

Note: This is a comprehensive form and parts inappropriate to a particular application should be cancelled. In the case of an application by the inventor, only parts 1, 4 and 6 of this form are appropriate, together with part 5 if a Patent of Addition is applied for.

(a) Insert (in full) name, address and nationality of applicant(s)

1. I/We (a) RANK PRECISION INDUSTRIES LIMITED trading as THE RANK ORGANISATION RANK TAYLOR HOBSON DIVISION, a British Company, of 104, Stoughton Street, Leicester.

(b) Delete the words which are not applicable

(c) Insert title of invention

am/are in possession of an invention which is described in the accompanying (b) provisional / complete specification under the title (c) [illegible]

"[illegible] OR RELATING TO OPTICAL OBJECTIVES OF VARIABLE [illegible] [illegible]".

(d) Insert name of inventor if included at (a)

(b) ~~(I~~ ~~(We~~ ~~(The said (d)~~ ....

~~claim to be the true and first inventor of the invention.~~

~~or~~

(e) Insert (in full) name, address and nationality of inventor(s) if not included at (a)

2. ~~I~~/We believe (e) Gordon Henry COOK, British Subject, of 68, Stoughton Road, Oadby, in the County of Leicester, and Peter Arnold MERIGOLD, British Subject, of "Ribblesdale", 4[illegible], Sedgefield Drive, Thurnby, in the County of Leicester,

to be the true and first inventor s of the invention.

and (b) ~~(I~~ (we (the said RANK PRECISION INDUSTRIES LIMITED trading as THE RANK ORGANISATION RANK TAYLOR HOBSON DIVISION

(b) ~~(am~~ (are the ~~(is~~ (b) (assignee of the said inventor in respect of the right to (make this application. ~~(personal representative of the said inventor~~

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P.T.O.

3. (*b*) ~~(A part of the~~ (~~the invention~~ / ~~invention~~) ~~was communicated from abroad to~~ (*h*) (~~me~~ / ~~us~~ / ~~the said~~

....

....

(*f*) Insert (in full) name and address and nationality of communicator.

by (*f*) ....

....

....

Use of the invention in the United Kingdom before the date of the application for a patent is, in general, a lawful ground of objection.

4. I/We declare that to the best of my our knowledge and belief the statements made above are correct and there is no lawful ground of objection to the grant of a patent to me/us on this application and I/we pray that a patent may be granted to me/us for the said invention.

5. And ~~I~~/We ~~request that the patent may be granted as a PATENT OF ADDITION to~~

(b) ~~(patent No.~~ ....
~~(the patent to be granted on application No.~~ ....

6. And ~~I~~/We request that all notices, requisitions, and communications relating to this application may be sent to A. P. [illegible],

(*g*) The address must be in the United Kingdom.

at (*g*) Chancery House, 53/64, Chancery Lane, London, W.C.2.

....

(*h*) Delete if not applicable.

(*h*) who is/are hereby appointed to act for me/us.

FOR AND ON BEHALF OF
RANK PRECISION INDUSTRIES LTD.

(*i*) To be signed by applicant(s).

(*i*) ....[signature]..............................

..............................SECRETARY..............................

Declaration to be signed by anyone named as inventor in part 2 who is not an applicant.
~~I~~/We assent to the making of this application.

Gordon Henry Cole

Peter Arnold [illegible]

....

The Comptroller,
The Patent Office, 25 Southampton Buildings,
Chancery Lane, London, W.C.2.

NOTICE TO INVENTORS

Attention of applicants is drawn to the desirability of avoiding publication of inventions relating to any article, material or device intended or adapted for use in war (Official Secrets Acts 1911 and 1920).

In such cases, after an application for a patent has been filed at the Patent Office, the Comptroller will consider whether publication or communication of the invention should be prohibited or restricted under Section 18 of the Act and will inform the applicant if such prohibition is necessary. Applicants are reminded that, under the provision of this Section, applications may not be filed abroad without written permit or unless an application has been filed not less than six weeks previously in the United Kingdom for a patent for the same invention and no direction prohibiting publication or communication has been given.

Case 373.

PATENTS ACT 1949.

14 SEPT 1962

FORM 2. 35088 1962

PROVISIONAL SPECIFICATION.

"IMPROVEMENTS IN OR RELATING TO OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH".

We, RANK PRECISION INDUSTRIES LIMITED trading as THE RANK ORGANISATION RANK TAYLOR HOBSON DIVISION, a British Company, of 104, Stoughton Street, Leicester, do hereby declare this invention to be described in the following statement:-

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This invention relates to an optical objective of the "zoom" type, that is of the type having relatively movable members whereby under the control of a zoom control element the equivalent focal length of the objective can be continuously varied throughout a range, whilst maintaining constant position of the image plane, whereby the size of the image can be varied. Accommodation for change of object position is usually achieved by imparting an additional movement to the front member of the objective.

Many difficulties arise in the design of such objectives, and one of the problems facing designers of today is to achieve an increased range of variation of equivalent focal length and, where possible, also an increased angular field of view. Attempts to achieve this usually involve the use of relatively complicated movable members in the objective in order to make it possible in such movable members to stabilise the aberrations throughout the range of variation, such stabilised aberrations then being compensated in a stationary rear member of the objective which also serves to locate the resultant image plane in a convenient position. This in turn involves the use of relatively large and heavy movable members and not only increases the bulk and size of the complete objective, but also presents severe mechanical problems in controlling the movements, especially bearing in mind that at least one of the movable members must necessarily perform a movement bearing a non-linear relationship to the movement of the zoom control element. Many attempts to extend the range of variation of the equivalent focal length have failed, because they have demanded departures from linearity

of movement which are impracticable mechanically, and often too because they have involved an increase in the bulk and size of the objective to unmanageable proportions or have introduced too severe optical difficulties in achieving aberration correction.

One way of reducing the mechanical complexities is so to arrange the system that the front member does not participate in the zooming movements for varying the equivalent focal length, so that this member is concerned only with focussing movements and is relieved of the complication of superimposing focussing movements on zooming movements. Such an arrangement is utilised in the present invention, wherein the primary object is to provide an improved arrangement of the movable system of the objective, which can be employed with various different arrangements of the front member and will cooperate therewith to enable aberration stability to be achieved throughout a widely extended range of variation of the equivalent focal length of the objective.

The optical objective of the zoom type according to the present invention has four members of which the first (counting from the front) for a given object distance remains stationary during the zooming relative movements, the second and third are divergent and movable, and the fourth is convergent and stationary, the position of minimum separation between the second and third members occurring when the equivalent focal length of the objective is greater than half its maximum value in the range of variation, whilst the equivalent focal lengths f_B and f_C respectively of the movable second and third members lie respectively between 4 and 8

times the minimum value of the ratio of the equivalent focal length of the objective to the f/number of the objective in the range of variation and between 5 and 10 times such minimum ratio, the divergent movable second member consisting of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent compound component and performing during the range of variation a total axial movement lying between $1.5f_B$ and $2.5f_B$, whilst the divergent movable third member consists of a doublet component having a front surface concave to the front with radius of curvature between $0.5f_C$ and $1.0f_C$ and performs during the range of variation a total axial movement lying between $0.25f_C$ and $0.5f_C$

It is to be understood that the terms "front" and "rear", as used herein, relate respectively to the sides of the objective nearer to and further from the longer conjugate in accordance with the usual convention.

It should also be made clear that the term "internal "contact", when used in connection with a compound component, is intended to include, not only a cemented contact, but also what is commonly known as a "broken contact", that is one in which the two contacting surfaces have slightly different radii of curvature, the effective radius of curvature of such a broken contact being the arithmetic mean between the radii of curvature of the individual contacting surfaces, whilst the optical power of the broken contact is the harmonic mean between the optical powers of the individual contacting surfaces.

The characteristics of the movable second and third members above specified contribute towards keeping the overall

dimensions of the objective as small as possible and achieving the best compromise between the diameters and the relative apertures of the individual members of the objective, and also permit the front nodal points of the second and third members to be located as far forward as possible, thus making it possible, not only to accommodate the desired movements of the members without risk of fouling between the members and with minimum increase in the overall length of the objective, but also to achieve a good compromise between the diameters and relative apertures of the individual members, and at the same time to assist towards the desired stabilisation of the aberrations, especially of spherical aberration and coma, throughout a widely extended range of variation of the equivalent focal length of the objective.

The compound component in the divergent movable second member preferably includes at least one convergent element and at least one divergent element made of materials whose Abbé V numbers differ from one another by more than 25, thus permitting such second member to be individually corrected for chromatic aberration.

For assisting towards stabilisation of astigmatism and distortion, the radius of curvature of the front surface of the simple meniscus component of the second member preferably lies between $1.5f_B$ and $3f_B$, and further assistance towards stabilisation of astigmatism can be obtained by arranging for the radius of curvature of the rear surface of such component to lie between $0.66f_B$ and $1.0f_B$.

The front surface of the compound component of the second member is preferably concave to the front with radius of curvature between $1.5f_B$ and $3f_B$, the rear surface of such component being convex to the front with radius of curvature

between $3f_3$ and $6f_3$, thus assisting towards stabilisation of spherical aberration and coma.

Whilst such compound component may consist of a doublet component, it will usually be preferable for it to be in the form of a triplet component having a convergent element between two divergent elements. This, in view of the limited availability of suitable materials for the various elements, facilitates correction of chromatic aberration and the desired stabilisation of the other aberrations without excessive curvature of the individual surfaces.

The avoidance of excessive surface curvatures can also be assisted by employing for all the elements of the second member materials whose mean refractive indices are greater than 1.65, whilst the mean refractive indices of the materials of the elements of the compound component in such member do not differ from one another by more than 0.15. The arithmetic mean between the Abbé V numbers of the materials of the divergent elements in the second member preferably exceeds that of the convergent element or elements by at least 25, in order to assist in correcting such member for chromatic aberration.

The doublet component constituting the divergent movable third member preferably has a collective internal contact convex to the front with radius of curvature between $0.5f_C$ and f_C, the difference between the mean refractive indices of the materials of the two elements of such component lying between 0.05 and 0.15, whilst the difference between the Abbé V numbers of such materials exceeds 25. These features contribute towards the desired

stabilisation of spherical aberration and coma and also facilitate individual correction of the third member for chromatic aberration.

As in the case of the second member, it is preferable to employ materials for the elements of the third member having mean refractive indices greater than 1.65, in order to avoid excessive surface curvatures and thus facilitate the attainment of a wide relative aperture for the member.

A movable system arranged in the manner above described in accordance with the present invention is suitable for use with various different arrangements of the first member of the objective, but it is especially advantageous for such member to have one or more of the following characteristics:-

A) The first member is preferably convergent and may comprise a front meniscus doublet component with its front and rear surfaces concave to the front followed by two simple convergent components, the front surface of the doublet component having dispersive optical power lying numerically between $0.5/f_A$ and $1.0/f_A$, where f_A is the equivalent focal length of the first member. These features permit the rear nodal point of the first member to be far to the rear and preferably behind the rear surface of the member, for cooperation with the forwardly located front nodal point of the second member.

B) The internal contact of the meniscus doublet component of the first member may be dispersive and convex to the front with radius of curvature between $1.5f_A$ and $3f_A$, the difference between the mean refractive indices of the materials of the two elements of such doublet component being greater

than 0.15. These features contribute towards stabilisation of spherical aberration and astigmatism over the desired focussing range to suit different object distances.

C) The two simple components of the first member may together have a combined equivalent focal length between $0.75\underline{f}_A$ and $1.25\underline{f}_A$, their front surfaces each being convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4\underline{f}_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature may in turn be greater than $0.75\underline{f}_A$. These features assist towards stabilising the aberrations, especially spherical aberration and astigmatism, not only throughout the range of focussing adjustments, but also throughout the range of variation of equivalent focal length.

D) The rear surface of the rear component of the first member may be convex to the front with radius of curvature between $2\underline{f}_A$ and $7\underline{f}_A$. This feature contributes towards stabilisation of primary astigmatism throughout the range of focussing adjustments, and also of primary and higher order astigmatism throughout the range of variation of equivalent focal length.

E) The axial thickness of the meniscus doublet component of the first member may be less than $0.25\underline{f}_A$ and greater than the sum of the axial thicknesses of the two simple components thereof, such sum in turn being greater than $0.075\underline{f}_A$. These features contribute towards the desired rearward location of the rear nodal point of the first member.

F) The arithmetic mean between the Abbé V numbers of

the materials of the three convergent elements of the first member may exceed by at least 20 the Abbé V number of the material of the divergent front element of the meniscus doublet component of such member, thus facilitating individual correction of the first member for chromatic aberration.

G) The equivalent focal length f_A of the first member may lie between 1.2 and 2.4 times the maximum value of the ratio of the equivalent focal length of the objective to the f/number of the objective. This feature assists towards keeping the overall dimensions of the objective and also the relative aperture of the first member as small as possible.

Various combinations of the foregoing features may be incorporated in the arrangement of the first member, and it is especially advantageous to arrange such member in accordance with the invention forming the subject of the present applicants' British Patent Application No.35053 of 1962, filed concurrently herewith. The objective in accordance with the invention of such concurrent patent application has four members of which the first for a given object distance remains stationary during the zooming relative movements, the second and third members are movable, and the fourth is stationary, at least one of the movable second and third members being divergent, whilst the first member is convergent and comprises a front meniscus doublet component followed by two simple convergent components, such doublet component having a front surface concave to the front with dispersive optical power lying numerically between $0.5/f_A$ and $1.0/f_A$ and an internal contact which is dispersive and convex to the front with radius of curvature between $1.5f_A$ and $5f_A$, the difference

between the mean refractive indices of the materials of the two elements of such doublet component being greater than 0.15, whilst the two simple components of the first member together have a combined equivalent focal length between $0.75f_A$ and $1.25f_A$ and have their front surfaces convex to the front, the radius of curvature of the front surface of the first of such simple components being less than $4f_A$ and greater than twice the radius of curvature of the front surface of the second of such simple components, which latter radius of curvature is in turn greater than $0.75f_A$.

In all the arrangements according to the present invention, it is preferable for the iris diaphragm of the objective to be stationary and to be located behind the movable third member of the objective.

Numerical data for some convenient practical examples of zoom objective according to the present invention are given in the following tables, in which R_1, R_2.....designate the radii of curvature of the individual surfaces of the objective counting from the front, the positive sign indicating that the surface is convex to the front and the negative sign that it is concave thereto, D_1, D_2..... designate the axial thicknesses of the individual elements of the objective, and S_1, S_2...... designate the axial air separations between the components of the objective. The tables also give the mean refractive indices $\underline{n}_d$ for the $\underline{d}$-line of the spectrum and the Abbé V numbers of the materials from which the various elements of the objective are made, and in addition the clear diameters of the various surfaces of the objective.

The second section of each table gives the values of the three variable axial air separations between the four members of the objective for a number of representative positions, for which the corresponding values of the equivalent focal length F of the complete objective from its minimum value F_b to its maximum value F_a are also given, together with the corresponding values of log F.

Some of the tables also have a third section giving the equation defining an axial section through an aspheric surface provided in the stationary rear member of the objective, the radius of curvature given for such surface in the first section of the table being the radius of curvature at the vertex of the surface.

The dimensions in each table are given in terms of F_o.

Example 1.

Radius	Thickness or Air Separation	Refractive Index n_d	Abbé V Number	Clear Diameter.
R_1 − 5.0480				R_1 3.4435
	D_1 0.1410	1.7847	26.10	
R_2 + 9.0764				R_2 3.4750
	D_2 0.6250	1.51507	56.35	
R_3 − 4.0997				R_3 3.4870
	S_1 0.0031			
R_4 + 11.3636				R_4 3.3715
	D_3 0.2563	1.717	47.90	
R_5 − 15.7510				R_5 3.3610
	S_2 0.0031			
R_6 + 3.9224				R_6 3.1035
	D_4 0.2969	1.717	47.90	
R_7 + 17.1609				R_7 3.0707
	S_3 variable			
R_8 + 2.7753				R_8 1.7000
	D_5 0.0563	1.69734	56.10	
R_9 + 1.2154				R_9 1.4012
	S_4 0.3625			
R_{10} − 2.7397				R_{10} 1.4712
	D_6 0.0500	1.69734	56.19	
R_{11} + 3.1121				R_{11} 1.4092
	D_7 0.2125	1.7847	26.10	
R_{12} − 3.1121				R_{12} 1.3947
	D_8 0.0500	1.69734	56.19	
R_{13} + 5.7301				R_{13} 1.3412
	S_5 variable			
R_{14} − 1.3021				R_{14} 0.7807
	D_9 0.0375	1.69734	56.19	
R_{15} + 1.3021				R_{15} 0.8205
	D_{10} 0.1063	1.7847	26.10	
R_{16} + 9.8892				R_{16} 0.8300
	S_6 variable			
R_{17} + 13.8889				R_{17} 0.8865
	D_{11} 0.1250	1.524	58.57	
R_{18} − 1.8116				R_{18} 0.9017
	S_7 0.0031			
R_{19} + 1.8116				R_{19} 0.9157
	D_{12} 0.1250	1.524	58.87	
R_{20} − 8.3333				R_{20} 0.9102
	S_8 0.0031			
R_{21} + 1.0417				R_{21} 0.8858
	D_{13} 0.1250	1.524	58.87	
R_{22} + 3.1250				R_{22} 0.8602
	S_9 0.2375 (aspheric)			
R_{23} − 4.0770				R_{23} 0.7560
	D_{14} 0.2133	1.7283	28.66	
R_{24} + 1.0626				R_{24} 0.6907
	S_{10} 0.3175			
R_{25} + 5.1589				R_{25} 0.7197
	D_{15} 0.0625	1.7283	28.66	
R_{26} + 1.5001				R_{26} 0.7200
	D_{16} 0.1563	1.61452	56.22	
R_{27} − 1.5001				R_{27} 0.7225

s_3	s_5	s_6	F	log F
0.03023	2.54423	0.66658	1.00000	0.00
1.11409	1.40738	0.74357	1.77827	0.25
1.93430	0.60333	0.72521	3.16227	0.50
2.55076	0.16104	0.55125	5.62339	0.75
2.96233	0.16657	0.13414	10.00000	1.00

Equation for aspheric surface R_{23}

$$\underline{x} = -4.077 + \sqrt{16.62193 - \underline{y}^2} - 0.02459803\,\underline{y}^4 + 0.08809172\,\underline{y}^6$$
$$- 0.2440590\,\underline{y}^8 - 0.07442450\,\underline{y}^{10}$$

Example 11.

Radius	Thickness or Air Separation	Refractive Index n_d	Abbé V Number	Clear Diameter
R_1 − 7.2114				R_1 4.9192
	D_1 0.2014	1.7847	26.10	
R_2 + 12.9661				R_2 4.9642
	D_2 0.8928	1.51507	56.35	
R_3 − 5.8567				R_3 4.9814
	S_1 0.0045			
R_4 + 16.2336				R_4 4.8164
	D_3 0.3661	1.7170	47.90	
R_5 − 22.5012				R_5 4.8014
	S_2 0.0045			
R_6 + 5.6034				R_6 4.4335
	D_4 0.4241	1.7170	47.90	
R_7 + 24.5154				R_7 4.3867
	S_3 variable			
R_8 + 3.9647				R_8 2.4286
	D_5 0.0804	1.69734	56.19	
R_9 + 1.7362				R_9 2.1161
	S_4 0.5178			
R_{10} − 3.9153				R_{10} 2.1018
	D_6 0.0714	1.69734	56.19	
R_{11} + 4.4458				R_{11} 2.0132
	D_7 0.3036	1.7847	26.10	
R_{12} − 4.4458				R_{12} 1.9925
	D_8 0.0714	1.69734	56.19	
R_{13} + 8.2572				R_{13} 1.9161
	S_5 variable			
R_{14} − 1.8601				R_{14} 1.1353
	D_9 0.0536	1.69734	56.19	
R_{15} + 1.8601				R_{15} 1.1721
	D_{10} 0.1518	1.7847	26.10	
R_{16} + 14.1274				R_{16} 1.1857
	S_6 variable			
R_{17} − 10.8095				R_{17} 1.2592
	D_{11} 0.1875	1.5168	64.20	
R_{18} − 1.9192				R_{18} 1.2861
	S_7 0.0045			
R_{19} + 2.6541				R_{19} 1.3110
	D_{12} 0.1875	1.5168	64.20	
R_{20} − 10.8725				R_{20} 1.3033
	S_8 0.0045			
R_{21} + 1.3446				R_{21} 1.2672
	D_{13} 0.1875	1.5168	64.20	
R_{22} + 2.9064				R_{22} 1.2220
	S_9 0.4375 (aspheric)			
R_{23} − 4.2315				R_{23} 1.0500
	D_{14} 0.3777	1.7283	28.66	
R_{24} + 1.9174				R_{24} 0.9680
	S_{10} 0.4714			
R_{25} ∞				R_{25} 1.0019
	D_{15} 0.0929	1.7283	28.66	
R_{26} + 2.3366				R_{26} 1.0088
	D_{16} 0.2304	1.61342	59.27	
R_{27} − 2.3366				R_{27} 1.0188
	S_{11} 0.0045			
R_{28} + 5.7670				R_{28} 1.0068
	D_{17} 0.2304	1.61342	59.27	
R_{29} − 5.7670				R_{29} 0.9770

S_3	S_5	S_6	F	log F
0.04318	3.63462	0.98790	1.00000	0.00
1.59156	2.01054	1.06300	1.77827	0.25
2.76329	0.86219	1.03962	3.16227	0.50
3.64395	0.29005	0.75109	5.62339	0.75
4.23190	0.23796	0.19524	10.00000	1.00

Equation for aspheric surface R_{23}

$$\underline{x} = -4.2315 + \sqrt{17.90939 - \underline{y}^2} - 0.01666305\,\underline{y}^4 + 0.02010143\,\underline{y}^6$$
$$- 0.00176346\,\underline{y}^6 - 0.00553320\,\underline{y}^{10}$$

Example III.

Radius			Thickness or Air Separation		Refractive Index n_d	Abbé V Number	Clear Diameter	
R_1	-	7.2114	D_1	0.2014	1.7847	26.10	R_1	4.9192
R_2	+	12.9661	D_2	0.8928	1.51507	56.35	R_2	4.9642
R_3	-	5.8567	S_1	0.0045			R_3	4.9014
R_4	+	15.2336	D_3	0.3661	1.7170	47.90	R_4	4.8164
R_5	-	22.5012	S_2	0.0045			R_5	4.8014
R_6	+	5.6034	D_4	0.4241	1.7170	47.90	R_6	4.4335
R_7	+	24.5154	S_3	variable			R_7	4.3867
R_8	+	3.9647	D_5	0.0804	1.69734	56.19	R_8	2.4296
R_9	+	1.7362	S_4	0.5178			R_9	2.1161
R_{10}	-	3.9138	D_6	0.0714	1.69734	56.19	R_{10}	2.1018
R_{11}	+	4.4458	D_7	0.3036	1.7847	26.10	R_{11}	2.0132
R_{12}	-	4.4458	D_8	0.0714	1.69734	56.19	R_{12}	1.9025
R_{13}	+	8.2572	S_5	variable			R_{13}	1.9161
R_{14}	-	1.8601	D_9	0.0536	1.69734	56.19	R_{14}	1.1195
R_{15}	+	1.8601	D_{10}	0.1518	1.7847	26.10	R_{15}	1.1721
R_{16}	+	14.1274	S_6	variable			R_{16}	1.1857
R_{17}		∞	D_{11}	0.1911	1.524	58.87	R_{17}	1.2830
R_{18}	-	2.3322	S_7	0.0045			R_{18}	1.3098
R_{19}	+	10.6292	D_{12}	0.1910	1.524	58.87	R_{19}	1.3238
R_{20}	-	10.6292	S_8	0.0045			R_{20}	1.3283
R_{21}	+	2.7812	D_{13}	0.2678	1.61342	59.27	R_{21}	1.3273
R_{22}	-	2.7812	S_9	0.0100			R_{22}	1.3060
R_{23}	-	2.5142	D_{14}	0.0893	1.72830	28.66	R_{23}	1.3049
R_{24}		∞	S_{10}	1.6928			R_{24}	1.2835
R_{25}		∞	D_{15}	0.0893	1.72830	28.66	R_{25}	0.9600
R_{26}	+	1.4266	S_{11}	0.0298			R_{26}	0.9600
R_{27}	+	1.6477	D_{16}	0.2929	1.69734	56.19	R_{27}	0.9600
R_{28}	-	2.7352					R_{28}	0.9600

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S_4	S_5	S_6	F	log F
	2.63462	1.0319	1.00000	0.00
1.59156	2.01054	1.1076	1.77827	0.25
2.76329	0.86219	1.08422	3.16227	0.50
3.64325	0.23005	0.83569	5.62339	0.75
4.23190	0.23796	0.23984	10.00000	1.00

In all these examples, the maximum value F_n of the equivalent focal length F of the objective is ten times the minimum value F_o thereof. Example I is corrected for a relative aperture *f*/4.0, whilst Examples II and III are each corrected for a relative aperture *f*/2.8. Examples II and III differ from one another solely in the stationary rear member, the front three members being identical in the two examples. Such front three members are in fact similar to the front three members of Example I, the dimensions being scaled up from those of Example I in the ratio of the *f*/numbers, that is in the ratio 4.0/2.8. The rear members in Examples II and III are, however, not scaled-up versions of the rear member of Example I. All three examples cover a semi-angular field of view varying from 27 degrees at F_o to 3 degrees at F_n.

The iris diaphragm in all three examples is stationary and is located between the movable third member and the stationary fourth member. In Example I the diaphragm is 0.0625 F_o in front of the surface R_{17} and has diameter 0.6568 F_o, whilst in Example II the diaphragm is 0.0929 F_o in front of the surface R_{17} and has diameter 1.2240 F_o, and in Example III it is 0.1375 F_o in front of the surface R_{17} and has diameter 1.224 F_o.

The back focal distance from the rear surface of the objective to the image plane is 2.8301 F_o in Example I, 2.6761 F_o in Example II and 2.3027 F_o in Example III.

All three examples incorporate the invention of the concurrent British Patent Application above mentioned.

The equivalent focal length f_A of the stationary first member is + 4.4551 F_o in Example I and + 6.3644 F_o in Examples II and III; the equivalent focal length f_B of the movable second member is - 1.4703 F_o in Example I and - 2.1004 F_o in Examples II and III; the equivalent focal length f_C of the movable third member is - 1.8176 F_o in Example I and - 2.5966 F_o in Examples II and III; and the equivalent focal length f_D of the stationary fourth member is + 1.4753 F_o in Example I, + 2.1286 F_o in Example II and + 2.3232 F_o in Example III; the positive and negative signs respectively indicating convergence and divergence.

In all three examples, the convergent stationary front member consists of a meniscus doublet component followed by two convergent simple components. The front surface R_1 of the doublet component is concave to the front and has dispersive optical power numerically equal to $0.1554/F_o$ or $0.6924/f_A$ in Example I, $0.1088/F_o$ or $0.6924/f_A$ in Examples II and III. The internal contact R_2 of the doublet component is dispersive and convex to the front and has radius of curvature equal to 2.0373 f_A in all three examples. The difference between the mean refractive indices of the materials of the two elements of such doublet component is .27 in all three examples.

The combined equivalent focal length of the two simple components of the first member is 4.0013 F_0 or 0.8981 f_A in Example I, 5.7162 F_0 or 0.8981 f_A in Examples II and III. The radius of curvature R_4 of the front surface of the first of such simple components is 2.5907 f_A in all three examples, whilst the radius of curvature R_6 of the front surface of the other simple component is 0.8304 f_A in all three examples.

The rear surface R_7 of the rear component of the first member is convex to the front and has radius of curvature equal to 3.8520 f_A in all three examples.

The axial thickness $(D_1 + D_2)$ of the meniscus doublet component of the first member is 0.7660 F_0 or 0.1719 f_A in Example I and 1.0942 F_0 or 0.1719 f_A in Examples II and III. The sum of the axial thicknesses $(D_3 + D_4)$ of the two simple components of the first member is 0.5532 F_0 or 0.1242 f_A in Example I and 0.7902 F_0 or 0.1242 f_A in Examples II and III.

The arithmetic mean between the Abbé V numbers of the materials of the three convergent elements of the first member in all three examples is 50.72 and thus exceeds the Abbé V number of the divergent front element of the first member by 24.62.

In Example I the maximum value of the ratio of the equivalent focal length of the objective to the f/number of the objective is 2.5 F_0, so that f_A is 1.7820 times such maximum value, whilst in Examples II and III such maximum ratio is 3.571 F_0, so that f_A is again 1.7820 times such maximum ratio.

The position of minimum separation between the movable second and third members occurs when the equivalent focal

length of the objective is 7.45 F_o in all three examples. The equivalent focal lengths f_B and f_C respectively of the second and third members are respectively 5.8812 and 7.2704 times the minimum value of the ratio of the equivalent focal length of the objective to the f/number of the objective in all three examples.

The movable second member in all three examples consists of a divergent simple meniscus component with its surfaces convex to the front followed by a divergent triplet component having a convergent element between two divergent elements, and its total axial movement in the range of variation is numerically equal to 1.9942 f_B.

The front and rear surfaces R_8 and R_9 of the simple meniscus component of the second member respectively have radii of curvature numerically equal to 1.8876 f_B and 0.8266 f_B. The front and rear surfaces R_{10} and R_{13} of the triplet component of such member respectively have radii of curvature numerically equal to 1.8634 f_B and 3.9312 f_B.

The movable third member in all three examples consists of a doublet component whose front surface R_{14} is concave to the front with radius of curvature numerically equal to 0.7164 f_C, and the total axial movement of such member is numerically equal to 0.3050 f_C.

The internal contact R_{15} of the doublet component of the third member is collective and convex to the front and has radius of curvature numerically equal to 0.7164 f_C. The difference between the mean refractive indices of the materials of the two elements of such doublet component is .0874 and the difference between their Abbé V numbers is 30.09.

In all three examples, the various aberrations are well stabilised in the front three members throughout the range of variation of equivalent focal length of the objective and also throughout the focussing range, and the stationary rear member serves to balance out such residual stabilised aberrations, and also to locate the resultant image plane in a convenient position. The construction of such member may thus vary widely. In Examples I and II, such rear member may be described as of modified Cooke triplet construction, wherein the strong convergent power needed at the front to deal with the relatively widely divergent beam received from the third member is achieved by the use of three simple convergent components, which are followed by a simple divergent component and either a convergent doublet component as in Example I or a convergent doublet component followed by a convergent simple component as in Example II. In these two examples an aspheric surface is used in order to assist in balancing out the residual stabilised aberrations of the front three members without undue increase in the overall length of the objective, such aspheric surface being the front surface R_{23} of the simple divergent component, where it can be employed for the simultaneous correction of spherical aberration and coma with minimum effect on oblique aberrations. In Example III, a somewhat different type of stationary rear member is used, which may be described as of modified Petzval construction. In this case, six simple components are used, the first three again being convergent in order to give the necessary strong convergent power at the front, whilst the next two are divergent and the sixth is convergent. Although no aspheric surface is used in the

actual example given, some further improvement in aberration correction could be achieved by incorporating such a surface.

It will be appreciated that, although it is preferred to employ a front member arranged in accordance with the invention of the concurrent British patent application above mentioned, this is by no means essential to the invention and other arrangements of the front member may also be advantageously used in cooperation with the movable system above described.

A. F. Pollinger

AGENT FOR THE APPLICANTS.

#9

U.S. D..ARTMENT OF COMMERCE
Patent Office

Address Only: COMMISSIONER OF PATENTS
Washington, D.C. 20231

March 22, 1973

Holcombe, Wetherill & Brisebois
2001 Jefferson Davis Hwy.
Suite 307
Arlington, Va. 22202

In re Gordon H. Cook, et al
Serial No. 152,254
Filed June 11, 1971
For: Optical Objectives of Variable Equivalent Focal Length

Gentlemen:

Receipt is acknowledged of papers filed on March 9, 1973 purporting to comply with the requirements of Title 35, U.S. Code, Sec. 119 (1952), and they have been placed of record in the file.

Issue Control Officer
Issue and Gazette Division

7955

Mrs Shelton

IN THE UNITED STATES PATENT OFFICE

GORDON HENRY COOK et al

June 28, 1973

Serial No. 152,254

Filed: June 11, 1971

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

U.S. Patent No. 3,736,048

Exmr. Corbin

Group Art Unit 259

Granted: May 29, 1973

REQUEST FOR CERTIFICATE OF CORRECTION
UNDER RULE 322

Honorable Commissioner of Patents
Washington, D.C. 20231

Sir:

It is respectfully requested that the Official Letters Patent, above-identified, be corrected as per attached sheet.

Please correct the spelling of the assignee's name to read THE RANK ORGANISATION LIMITED.

The necessary claim of priority and certified copy were filed in the Patent Office on March 9, 1973, however this information was omitted from the heading of the Letters Patent.

Please note that these were clerical errors in the printing of the patent.

Respectfully submitted,

GORDON HENRY COOK et al

APPROVED

OCT 1 2 1973

L. C. Mason

FOR THE COMMISSIONER OF PATENTS

By Joseph F. Brisebois

Joseph F. Brisebois Reg.No. 15,965
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
df

95

IN THE UNITED STATES PATENT OFFICE

JUL 25 1973

In re application of

GORDON HENRY COOK et al

Patent No. 3,736,048

Granted: May 29, 1973

For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Request for Certificate of Correction filed June 28, 1973

NOTICE OF CHANGE OF ATTORNEY'S FIRM NAME AND ADDRESS

Hon. Commissioner of Patents
Washington, D. C. 20231

Sir:

This will advise that as of August 1, 1973, the firm name and address of the undersigned attorneys of record in the above case will be:

BRISEBOIS & KRUGER
Suite 612
2361 Jefferson Davis Highway
Arlington, Virginia 22202

Respectfully submitted,

HOLCOMBE, WETHERILL & BRISEBOIS

By [signature]
Joseph F. Brisebois - Reg. 15,965

IN THE UNITED STATES PATENT OFFICE

In re application of | November 6, 1972
GORDON HENRY COOK et al
Serial No. 152,254 | Gr.Art Unit 259
Filed June 11, 1971
For: OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH | Exr. J. K. Corbin

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LETTER TO OFFICIAL DRAFTSMAN

Hon. Commissioner of Patents
Washington, D.C. 20231

Sir:

Please correct the surface R_7 in each of Figures 1-6 to show it as slightly convex to the front, as indicated in red on the attached prints, and charge the cost of this work to our Miscellaneous Account No. 08-2720, Order No. 53.

Respectfully submitted,

GORDON HENRY COOK et al

By [signature]
Joseph F. Brisebois Reg.15,965
HOLCOMBE, WETHERILL & BRISEBOIS

521-1550
JFB:gw

Line	1 Code	Serial Number	Filing Date	2 Status	Patent Number	Patent Date
104	72	309,207	9/16	03		
105						
106						
107						
108						
109						
110						
111						
112						
113						
114						
115						
116						
117						

CONDITION AND STATUS CODES FOR CONTINUING DATA

CODE	CONDITION
01	Now Patented
03	Now Abandoned
71	A continuation of (including streamline)
81	which is a continuation of
72	A continuation-in-part of
82	which is a continuation-in-part of
75	and a continuation-in-part
73	A substitute for
74	A division of
84	which is a division of
86	; said
90	and
91	and a continuation of
92	, each

NOTE: When the codes 86 and 92 are used they must be followed by a code in the series 80 (81, 82, or 84); the conditions beginning with "which is....".

MPI Family Report (Family Bibliographic and Legal Status)

In the MPI Family report, all publication stages are collapsed into a single record, based on identical application data. The bibliographic information displayed in the collapsed record is taken from the latest publication.

Report Created Date: 2009-11-24

Name of Report:

Number of Families: 1

Comments:

Table of Contents

1. US3736048A 19730529 RANK ORGANISATION LTD
OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH 1

Family1

1 records in the family.

US3736048A 19730529 [no drawing available]

(ENG) OPTICAL OBJECTIVES OF VARIABLE EQUIVALENT FOCAL LENGTH

Assignee: RANK ORGANISATION LTD

Inventor(s): COOK G H ; MERIGOLD P A

Application No: US 3736048D A

Filing Date: 19710611

Issue/Publication Date: 19730529

Abstract: (ENG) A zoom lens having an improved zooming range and comprising a convergent first member which for a given object distance remains stationary during the zooming relative movements, an axially movable divergent second member behind the first member having equivalent focal length fb lying numerically between 4 and 8 times the minimum value of the ratio of the equivalent focal length of the complete objective to the f-number of the objective in the range of variation, an axially movable divergent third member behind the second member having equivalent focal length fC lying numerically between 5 and 10 times the minimum value of such ratio, a stationary convergent fourth member behind the third member, a zoom control element, and means whereby operation of the zoom control element causes the zooming relative movements to be effected, wherein the total axial movement of the second member in the range of variation lies numerically between 1.5fB and 2.5fB and the total axial movement of the third member in the range lies numerically between 0.25fC and 0.5fC, the minimum axial separation between the second and third members occurring when the equivalent focal length of the object is greater than half its maximum value in the range of variation, the movable divergent second member consisting of a divergent simple meniscus component with its surfaces convex to the front and a divergent compound component behind such simple component, and the movable divergent third member consisting of a doublet component having its front surface concave to the front with radius of curvature lying numerically between 0.5fC and 1.0fC.

Priority Data: US 15225471 19710611 A I;

Related Application(s): 04/309208 19630916 US ABANDONED

IPC (International Class): G02B01517

ECLA (European Class): G02B01517

US Class: 359683; 359688; 359708

Publication Language: ENG

Filing Language: ENG

Agent(s): Holcombe, Wetherill & Brisebois

Examiner Primary: Corbin, John K.

Assignments Reported to USPTO:

Reel/Frame: 04864/0130 **Date Signed:** 19871021 **Date Recorded:** 19880502

Assignee: RANK TAYLOR HOBSON LIMITED, 2 NEW STAR ROAD, LEICESTER, LE4 7JQ, UNITED KINGDOM A CORP. OF UNITED KINGDOM

Assignor: RANK ORGANISATION PLC. THE.

Corres. Addr: LERNER, DAVID, LITTENBERG KRUMHOLZ & MENTLIK 600 SOUTH AVENUE WEST WESTFIELD, NEW JERSEY 07090

Brief: ASSIGNMENT OF ASSIGNORS INTEREST.

Legal Status:

Date	+/-	Code	Description
19880502	()	AS	New owner name: RANK TAYLOR HOBSON LIMITED, 2 NEW STAR ROAD, LEICE; : ASSIGNMENT OF ASSIGNORS INTEREST.;ASSIGNOR:RANK ORGANISATION PLC, THE,,REEL/FRAME,004864/0110; Effective date: 19871021;